ENVIRONMENTAL IMPACT ASSESSMENT
FOR THE
ADDITION OF COAL AS A FUEL
FOR THE
CABRAS ISLAND POWER PLANT

Prepared For
The Guam Energy Office

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in Association With
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TABLE OF CONTENTS

LIST OF FIGURES

FOREWORD

Since the oil embargo of 1973, the cost of oil to fuel the electric power generating industry has increased approximately 10 fold. This increase has caused electric utilities to convert to coal wherever possible. Conversion is hampered by the fact that many oil burning plants are not near a rail head or waterway to receive coal and may not have the area necessary for the stockpiling of coal.

World market pricing of crude oil has changed dramatically and is now determined by OPEC, a foreign cartel. This group is influenced not only by demand and supply, but is also involved in world politics. The consensus at the present time is that crude oil prices have levelled off, but that this situation will not last for the long term.

Of considerable influence on the near future price of oil for power generation is the decision of major U.S. oil companies to use resid, the end product or residual in the refining process normally used as boiler fuel, as fuel stock in their reformate plants to convert resid to gasoline, diesel fuel, and other products. This allows for effective use of resid, without leaving anything for power generation except the much higher priced distillates and diesel fuels, or resorting to the importation of resid from foreign sources. The foregoing will no doubt have an effect on the world price of residual fuel and accelerate conversion to coal in the U.S. and other countries.

I. INTRODUCTION

A. REGIONAL BACKGROUND INFORMATION

General Physiography of Guam

Guam is located in the western Pacific approximately 3,700 miles west of Hawaii and 1,500 miles south-southeast of Japan (Figure 1). Guam, with a total area of 580 sq. kilometers (225 sq. miles) is one of the larger and more complex islands of the Pacific. Guam is 30 miles long and 4 to 9 miles wide and the largest of the Mariana Islands.

The northern half of Guam is a broad limestone plateau bordered by steep cliffs that either fall directly to the sea or to narrow benches. The island is fringed by coral reefs. The island slopes from the north at an elevation of approximately 600 feet to 200 feet in the middle. The limestone of the northern plateau is so permeable that no streams exist, however, small intermittent streams do exist in central Guam.

The southern half of Guam is dissected volcanic upland. The majority of this area is mountainous, with several peaks reaching 1,000 feet. The western coast is bordered by a narrow coastal lowland and the eastern coast by limestone cliffs. Reefs surround the southern half of the island and they have been cut by numerous bays at the mouth of large streams which drain the volcanic uplands.

Climate of Guam

The climate of Guam is warm and humid. Mean temperature variations are slight throughout the year. Daytime temperatures are usually in the middle to high 80's and nighttime temperatures in the middle to high 70's. The humidity commonly varies between 65 to 80 percent in the late afternoon and 85 to 100 percent at night. Annual rainfall

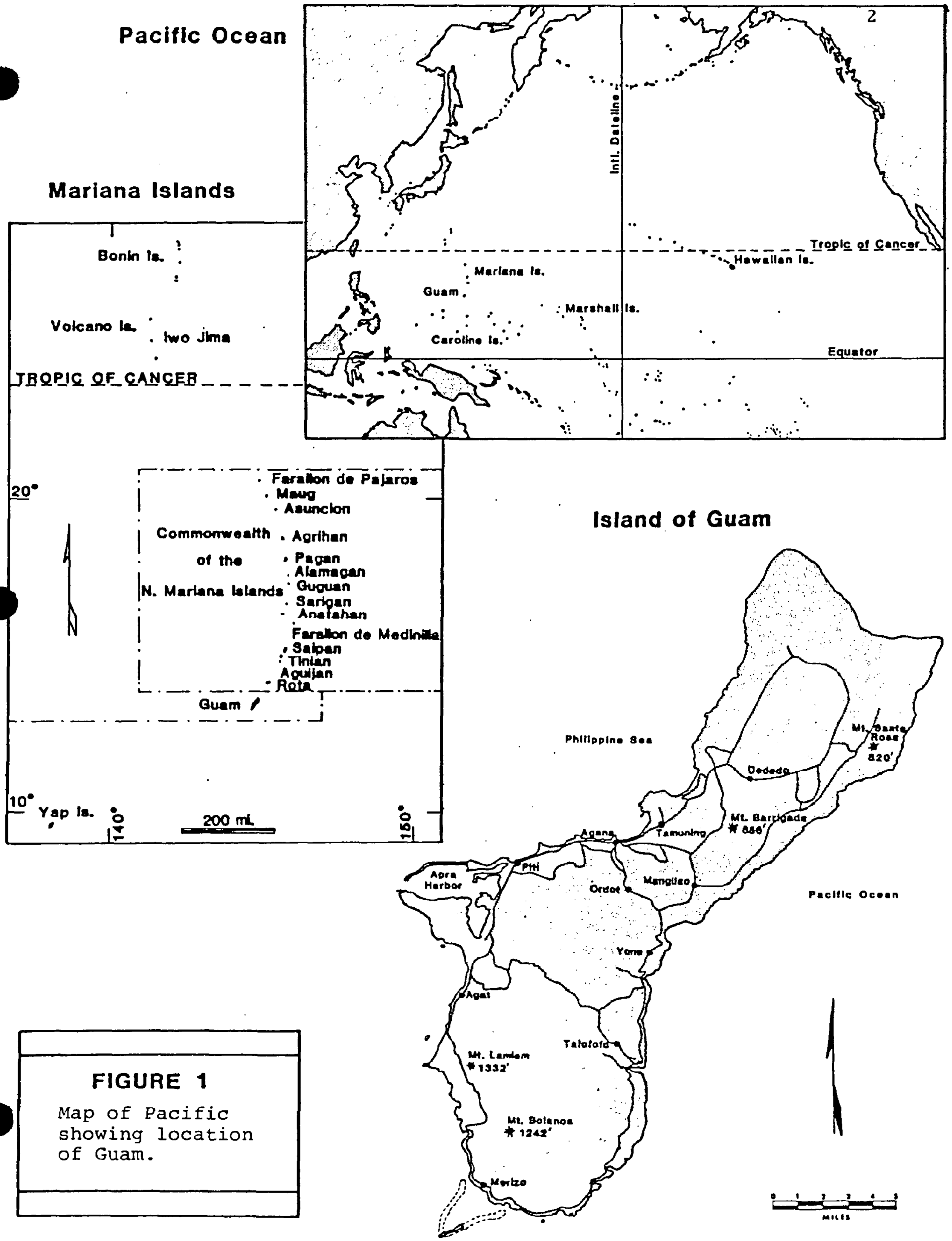


FIGURE 1

Map of Pacific showing location of Guam.

ranges from 85 to 115 inches. From January through May the constant tradewinds result in a well defined dry season broken by occasional showers.

July through November is the wet season when tropical storms and typhoons are moderately common. Chances are approximately two in three that one or more typhoons will pass within 120 nautical miles of Guam in any given year. Although typhoons can occur in any month they are more likely to occur during the wet season.

B. PURPOSE OF ACTION

In 1971 Mr. Walter F. Pinckert, senior partner of Walter F. Pinckert and Associates, then consultant to the Board of Directors, Guam Power Authority (GPA), was instrumental in the design and turnkey construction of the Cabras Island Power Plant for $33 million, which in 1984 dollars would cost approximately $133 million to replace (Figure 2). At the time Cabras Power Plant was commencing operation, Mr. Pinckert considered coal from Australia as an alternative source to fuel the system. However, because of difficulties with transportation, coal did not prove feasible or the best potential and tentative resource at the time.

More recent studies indicate that technical and economic considerations related to the use of coal by the Cabras Island Power Plant now make sense as a viable option for power generation. Of particular importance is the greatly improved schedule of ship movements in the Pacific Basin and the availability of large coal deposits in Australia.

The current depressed Australian and world economies present the Government of Guam with a rare opportunity to economically undertake this project and become independent before prices and cost of money

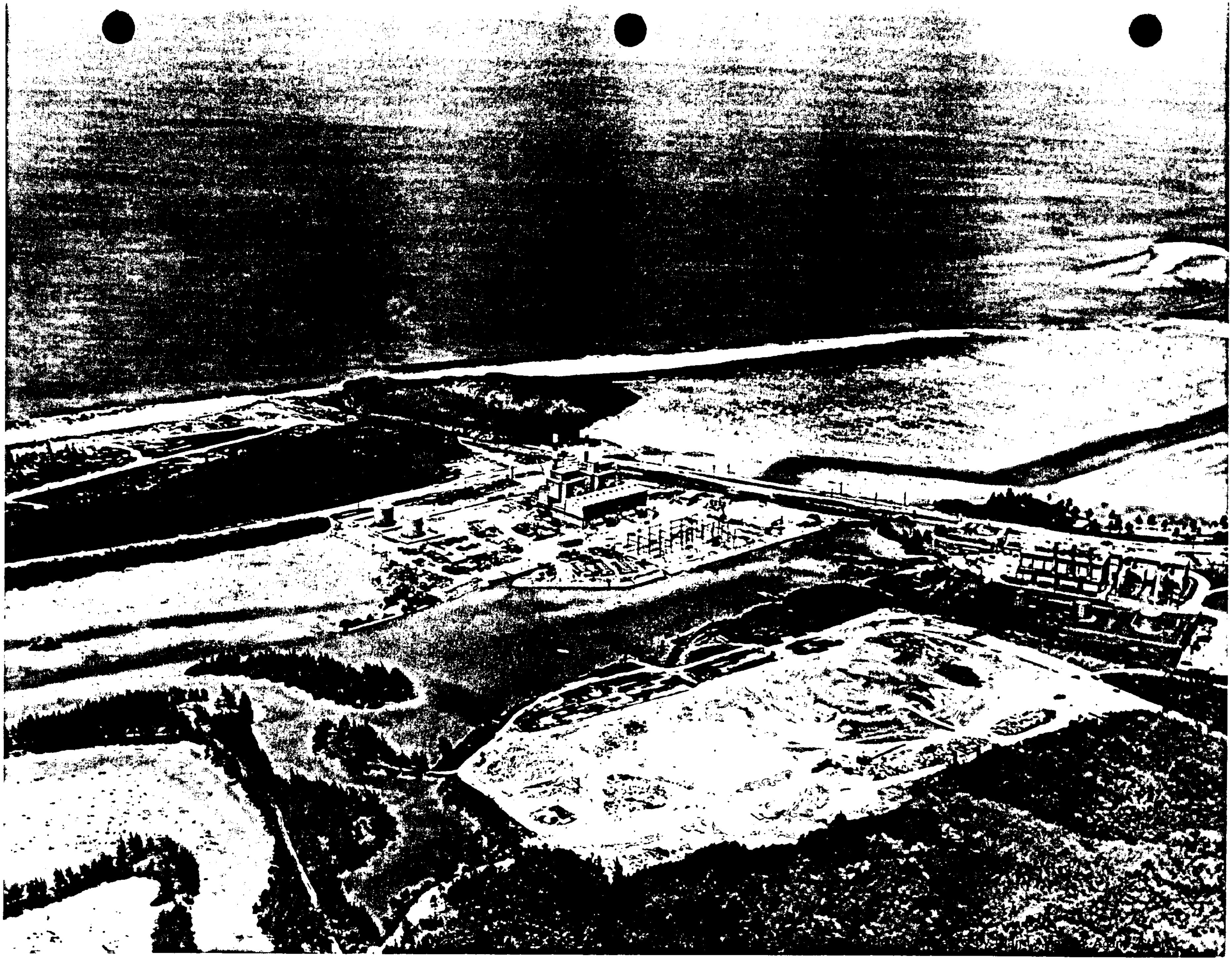


Figure 2: Overview of existing power generation facilities of Cabras Island .

escalate with the next recovery cycle of the U.S. and world economies. In essence, coal as energy, can provide the GPA and all electric power consumers with protection against the uncertainty of fuel oil prices and supply.

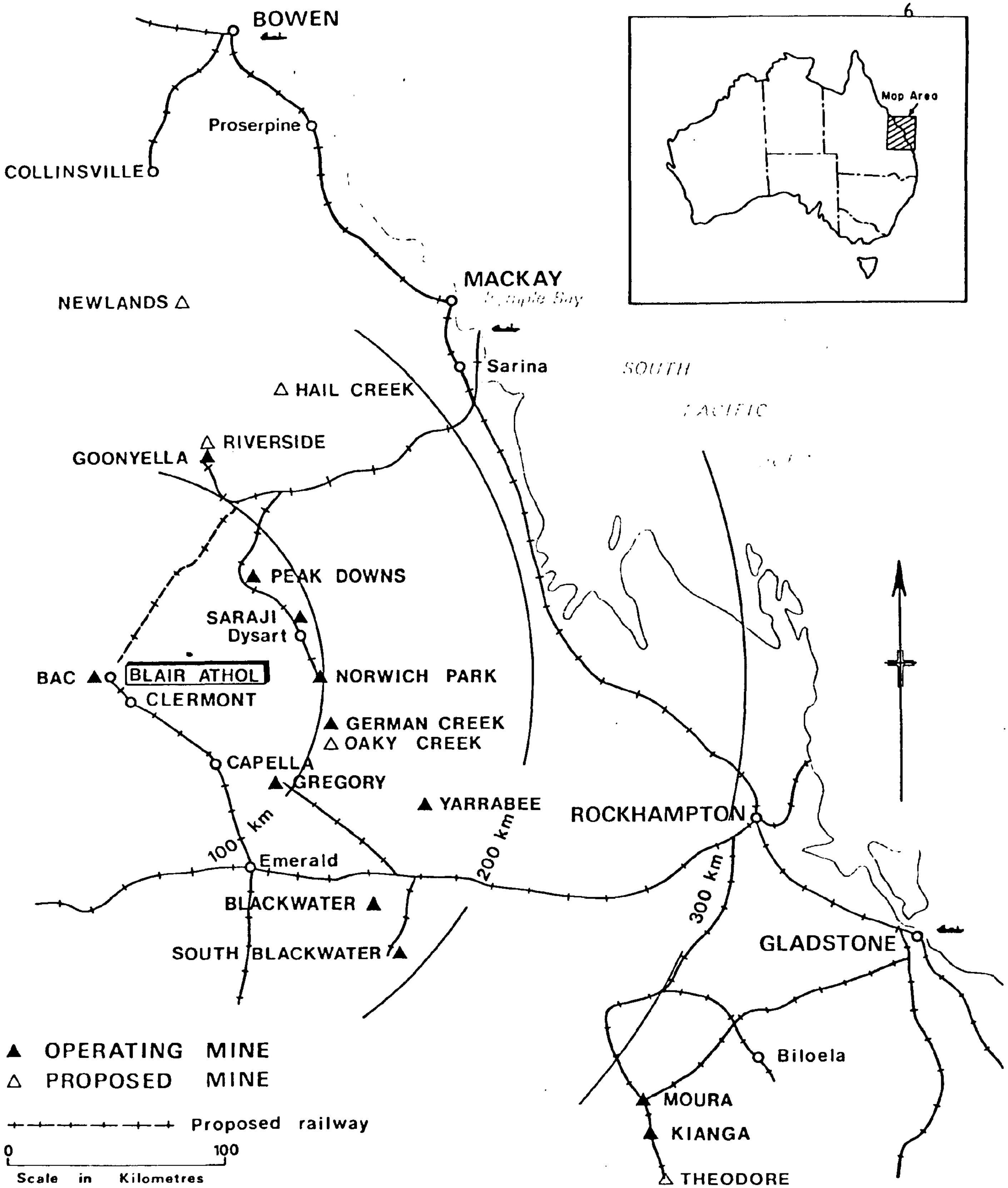
C. AVAILABILITY OF COAL

Source of coal suitable as fuel for boilers, usually referred to as "steaming coal" is Australia (Figures 3-5). Coal is one of the principle world market exports of Australia. Long term sales agreements can be (entered into) with one of several large producers on a competitive basis. Australian coal usually contains no more than half of one percent sulphur, one of the lowest in the world.

Coal from western states is available (Figure 6). Coal from these sources are also low in sulphur content, but not as low as Australian Coal. However, rail and sea distances are too great for competitive pricing. There are other sources such as China and Alaska.

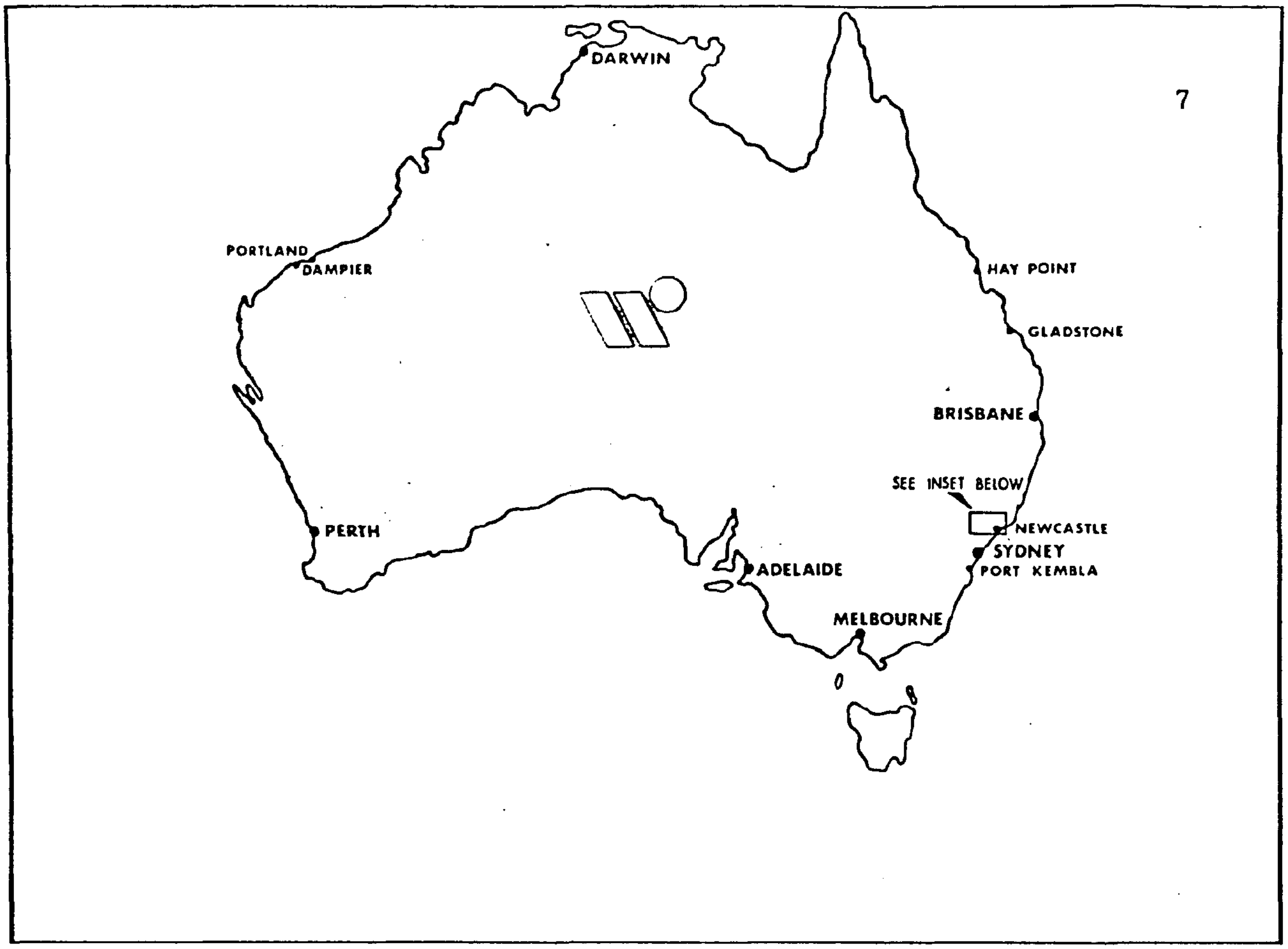
D. PROJECT LOCATION

The proposed coal fuel plant is to be located on land to be reclaimed adjacent to the existing Cabras Island Power Plant (Figures 7 and 8). The area is known commonly as the inner Piti Channel of Apra Harbor, Guam. The Piti Channel and Commercial Port areas in general have been greatly modified by dredging, land-filling and construction. A number of channelways, coastways and islets have been dredged and constructed in much of the area (Figures 2, 7 and 8). Two power plants discharge water used to condense exhaust steam into the east end of Piti Channel. Nearby a series of submerged pipelines cross the shallow flats from Cabras Island to Drydock Peninsula. Except for dredged channelways, much of the eastern end of the area is totally



BAC LOCATION MAP

Figure 3: Location of BAC Coal Mines, Australia.



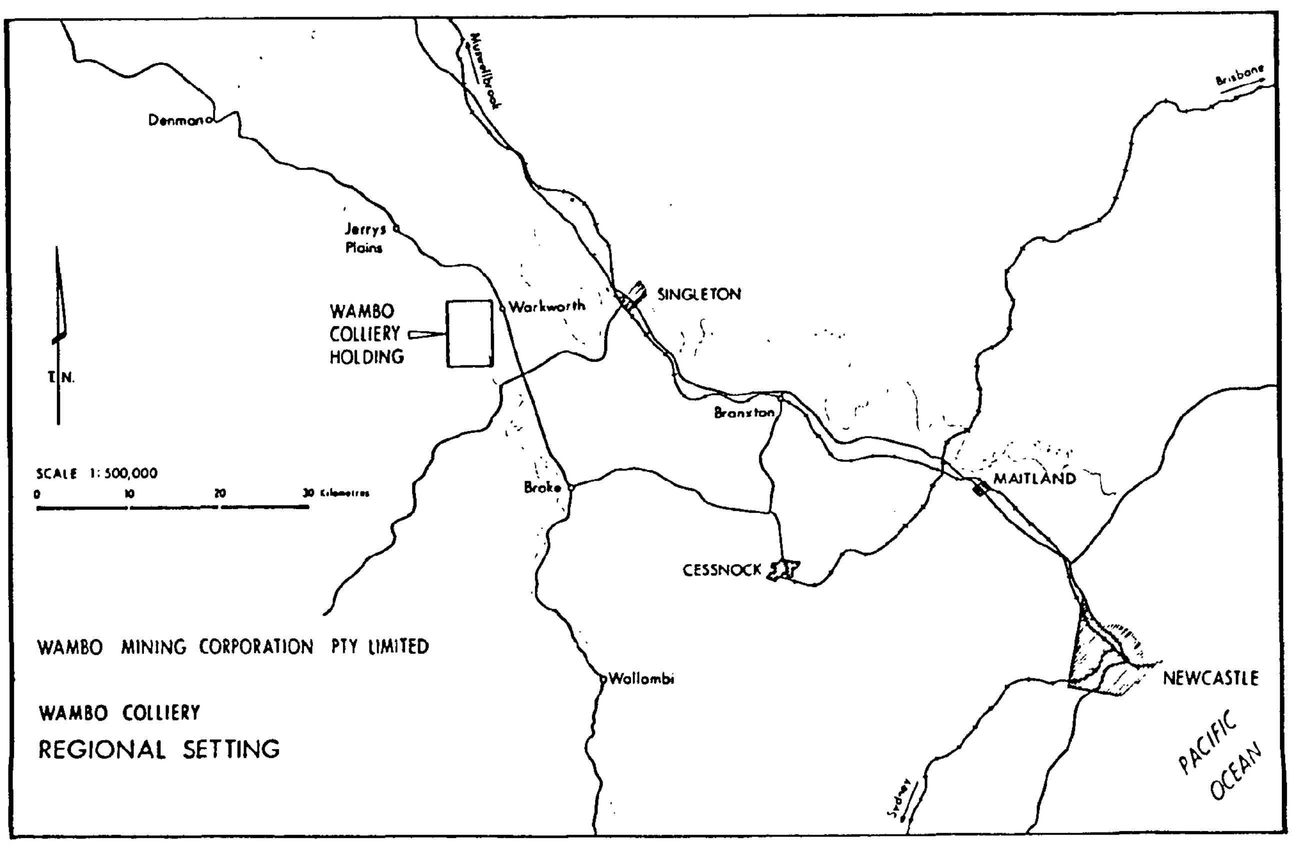


Figure 4: Location of Wambo Mining Corporation Coal Mines, Australia.

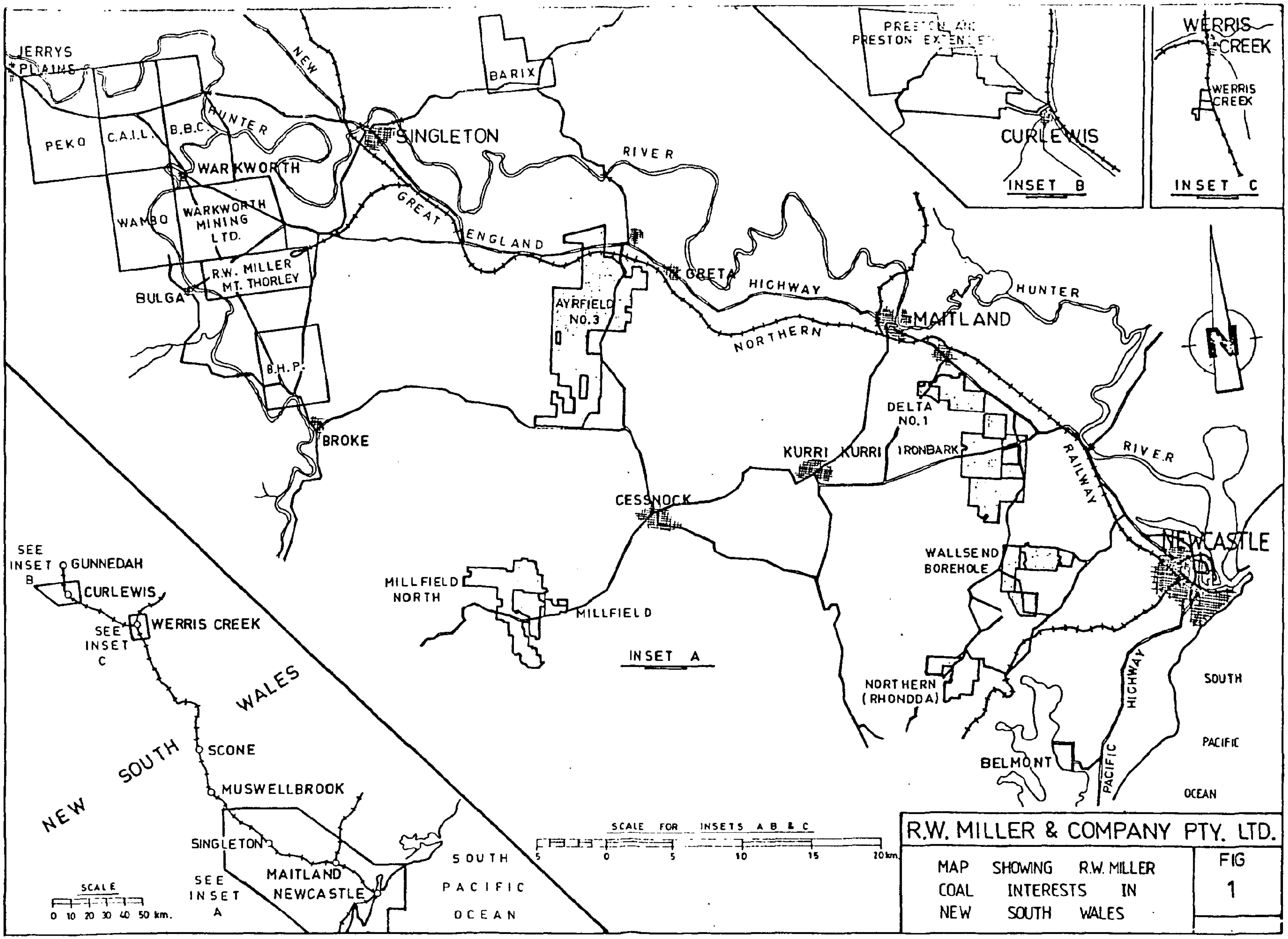


Figure 5: Location of R.W. Miller & Co. Coal Mines, Australia.

Coal fields and coal-producing districts of the United States

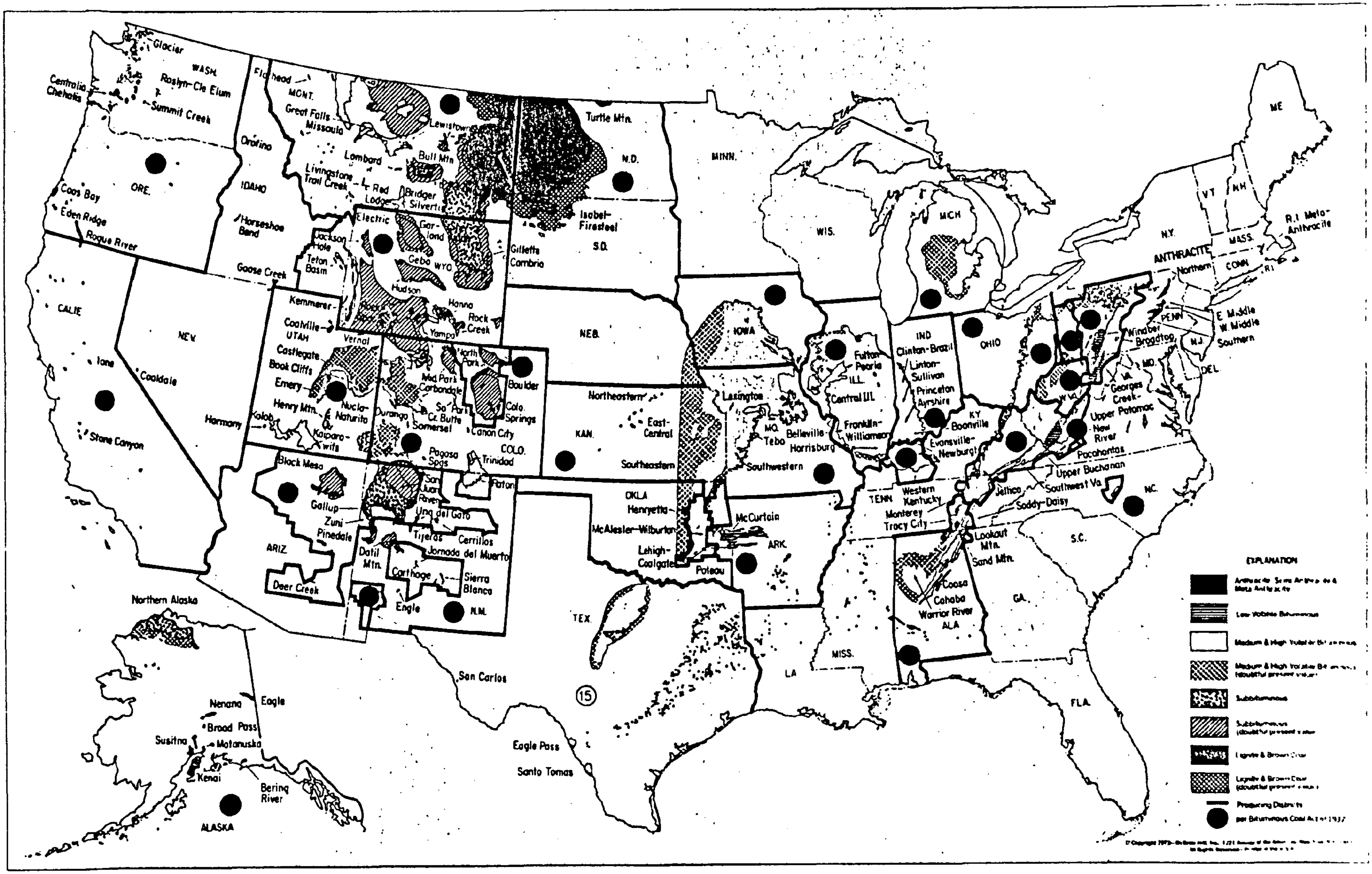


Figure 6: Coal fields and coal-producing districts of the United States.

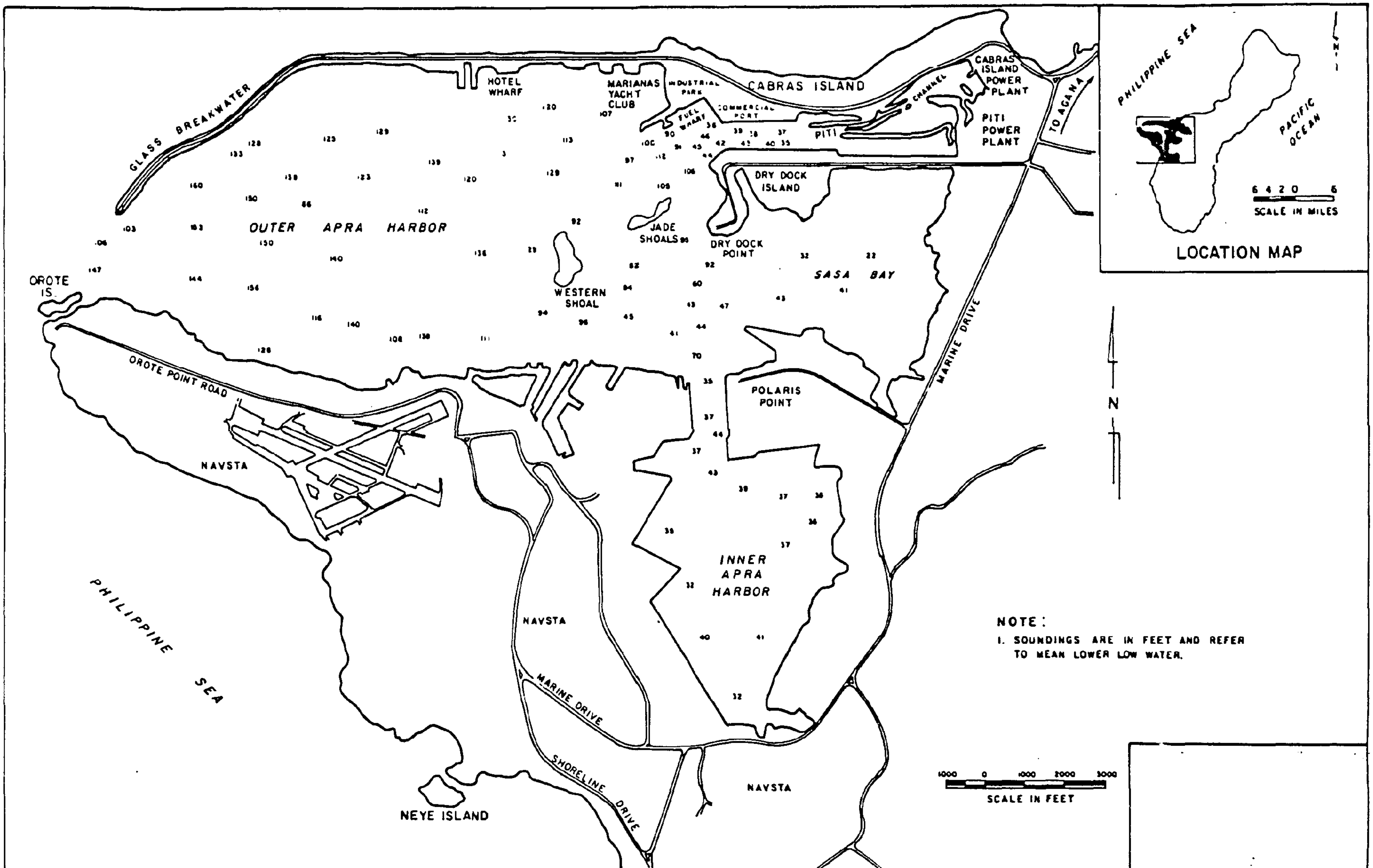


Figure 7: Location Map of Apra Harbor and the Piti Channel Area.

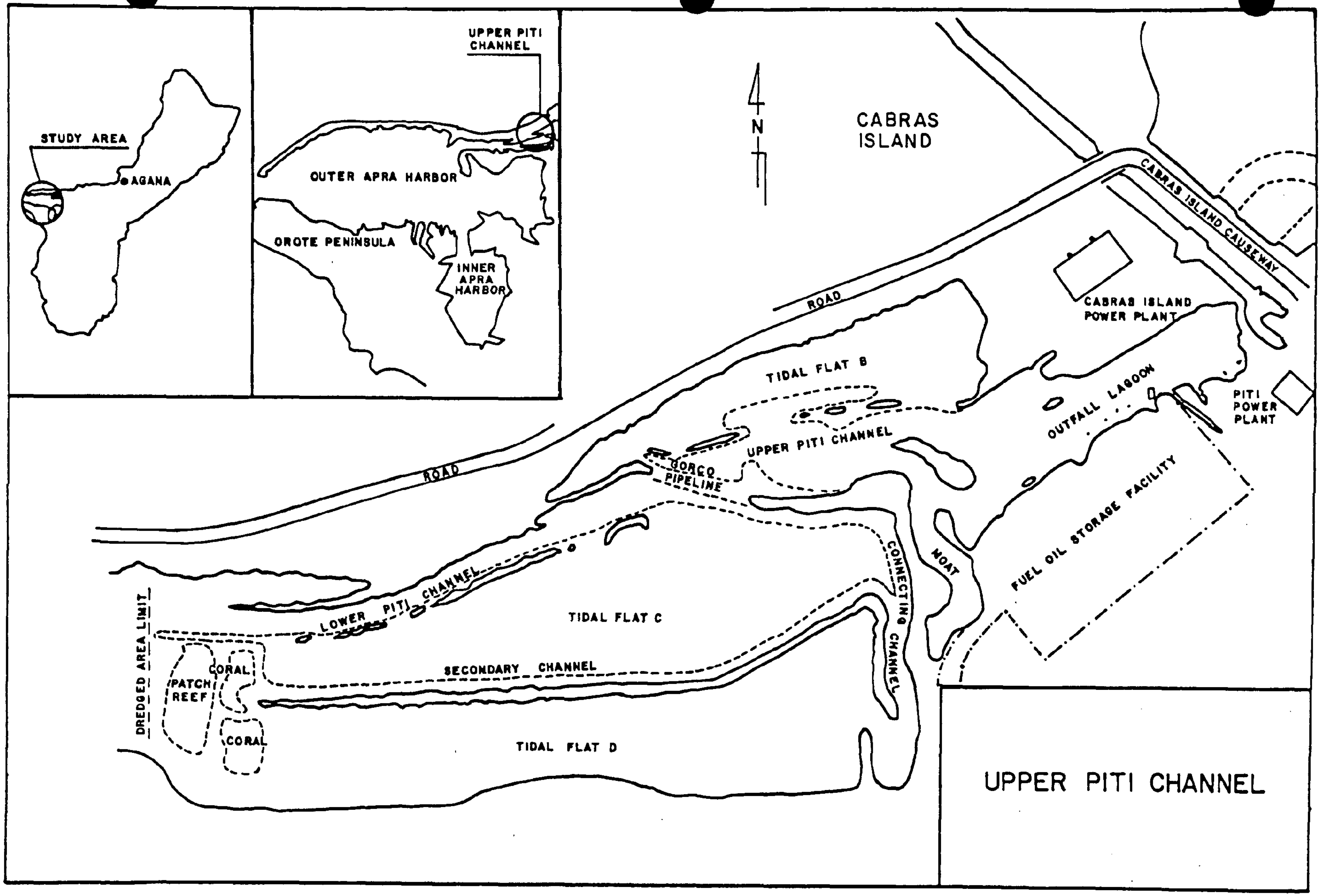


Figure 8: Map of the inner Piti Channel Area in Apra Harbor, Guam.

exposed during low spring tides. Commercial Port, U.S. Navy and GORCO fueling docks occupy the western end of the site which has been dredged to allow for docking of ships.

E. GENERAL PROJECT DESCRIPTION

The basic plan is to expand the existing Cabras Power Plant by the addition of two 70 MW coal burning steam boilers that would become an integral part of the Cabras Power generation facility. The existing oil fired steam boilers would be retained for standby and emergency operation. The Cabras steam turbo-generators would remain in operation and steam would be supplied by coal fired steam boilers.

Of the methods for handling coal, the following is considered feasible: Coal would be transported in five to six days time from Queensland's Bowen Coal Basin or other Australian port, to Apra Harbor in 50,000-60,000 Dead Weight Ton (DWT) Panamax class self-unloading colliers designed to unload at a rate of approximately 2,000 tons per hour. The Panamax class collier with a fully loaded draft of 43 ft and a length of 800 ft would anchor in Apra Harbor at approved anchorages within the 100 ft contour and discharge into 4,000 ton capacity coal barges eliminating the need for additional wharfage and berthing requirements at the Commercial Port. These 4,000 Ton coal barges will then be towed through the Piti Channel to a newly constructed wharf, where the coal would be unloaded and stockpiled on newly reclaimed land, adjacent to the CIPP.

This basic concept and proven system in coal transportation and handling could be carried out with minimum impact on the harbor and port environment, in harmony with the Apra Harbor and Commercial

Port of Guam Master Plan, with minimum capital investment for port and harbor improvements.

To accommodate the coal barges, the upper and lower Piti channels must be widened and deepened and a turning basin constructed. Spoils removed from the Piti Channel would be used to reclaim land for GPA's coal storage yard, barge wharfage, coal discharge and handling facilities adjacent to the CIPP.

F. OIL FIRED POWER PLANTS

There are three oil fired steam power plants on Guam, i.e. Cabras, Piti and Tanguisson. However, 80% of all power generated is supplied from Cabras. The Piti Plant is Navy owned including one unit in the Tanguisson Plant. The Cabras Plant and one unit in Tanguisson is GPA owned.

Piti and Tanguisson are not prime targets for conversion to coal, since their operation is limited to peak power shaving and to support maintenance outages. Thus conversion to coal, for Piti and Tanguisson plants, would not be cost effective.

G. LAND AVAILABILITY

By an act of Congress, GPA has fee simple title to all land underlying the Cabras Steam Power Plant site, including the submerged land that would be reclaimed for coal storage and handling.

II. ENVIRONMENTAL SETTING

A. ENVIRONMENT PRIOR TO PROPOSED ACTION

Regional Setting

A general description of Guam is found in the Introduction, Part I of this report. The location of Apra Harbor and many of its significant physical features, place-names and land uses are found on Figures 2, 7 and 8. Apra Harbor is a unique and valuable multiple-use resource for the people of Guam. It is the location of the island's only civilian and military port facilities, strategic US Naval logistical support facilities, heavy industry and power production; a focus of recreation boating, diving, and fishing; and has important archaeological and historic sites, unique wetlands and coral reefs and important habitats for endangered species of birds. The current operation of the US Naval Station encumbers the development of almost all new civilian construction except in the upper and lower Piti Channel area and the northern part of Sasa Bay. The Piti Channel area is characterized by two of the island's principle electric power generating plants, a popular and historic fishery and an often-used, small boat refuge. Much of Sasa Bay is designated as a pristine marine community and lies adjacent to an important mangrove wildlife habitat.

Oceanographic Setting

Apra Harbor is a deep lagoon enclosed on the north by the Glass Breakwater which was constructed on top of Calalan (submarine coral) Bank, Luminao (barrier) Reef, and Cabras Island. It is enclosed on the south by Orote Peninsula. The eastern portion of Apra Harbor was originally uncovered reef flat fronted by numerous patch reefs. Water once flowed freely between Cabras Island and the mainland. The eastern shoreline was lined with mangrove forest. Extensive dredging and filling during World War II created the channels and islets of the present Piti Channel area, Dry Dock Peninsula, and Dry Dock Point, the open Sasa Bay, and the filled Sumay and Polaris Point area. One of the notable remaining patch reefs is Jade Shoals, an elongated 2100-foot-long submarine ridge to the southwest of Commercial Port which reaches near the sea surface. The southwestern shoreline of Cabras Island and the Quarry area on the islands northern shore were likewise created during this period and in the late 1960's. According to the Guam Environmental Protection Agency (GEPA), this dredging and filling activity generated a large amount of silt that still remains trapped within the harbor and is constantly resuspended by passing ships and storms. Clay, silt, sand and coral-algal-mollusk rubble has accumulated over most of the deep lagoonal floor, but the floor of the Commercial Port is a uniform silty ooze.

The Piti Channel study area consists of mostly World War II-dredged channels, elongated islets of dredge tailings, tidal flats and an area of coral growth near the Commercial Port (Figure 2). Piti Channel was originally dredged in the late 19th century by the Spanish to provide access to Piti Village port. Today it serves as the principal channel for passing condenser cooling water into the harbor lagoonal area from the Navy's Piti Power Plant and the Guam Power Authority's Cabras Island Power Plant which are both located east of the Commercial Port. The depth of the Piti Channel averages about 6.6 feet below MLLW. The only known obstruction to dredging is the Guam Oil Refinery Company (GORCO) pipeline, which lies just below the bottom of the existing channel.

According to observations by Marsh and Gordon in 1973, the substrate in the channels and tidal flats consist primarily of loose sediments of sand and silt, with scattered rubble and occasional larger rocks. The channels are floored by moderate-to-large sized particles derived from coral skeletons and from the green calcareous alga *Halimeda*. The substratum within the present outfall lagoon, is a shifting sandy bottom. Scattered in this area and throughout the channel are pieces of scrap metal.

Historic and Cultural Resources

Early maps and information provided by the Guam Historic Preservation Officer indicate that Apra Harbor was a major population center from early times, having Chamorro latte (house foundation) sites on the eastern shores, fishing weirs between Piti Village and Cabras Island and rice fields in the interior lowlands. From the late 19th century through World War II, Piti Village was Guam's main port of entry. Cargo was brought by lighters up the Spanish-dredged Piti Channel. Since the early 20th Century, Cabras Island served as a coal bunkering and quarantine station. From about the 1920's or earlier, Piti Port served as a navy yard and was finally abandoned in the late 1940's. The existing concrete bulkhead, two abandoned and decrepit wooden piers and marine railways on the southeastern side of the old boat basin may have been constructed as early as the 1920's. A sunken boat of probable recent origin lies parallel to the old concrete pier.

A cultural reconnaissance survey of Cabras Island conducted in 1977 for the Apra Harbor Improvement Study found no prehistoric remains but did find foundations of the former quarantine station. There are no historic sites listed on the Guam or National Register of Historic Places located in the immediate project area. An old Chamorro latte or house site is located inland at the northeastern corner of Sasa Bay. The S.M.S. Cormoran, which was scuttled off Pier C, south of the Glass breakwater at the beginning of World War I, has been placed on the national Register. There are several other historic sites outside the study area in the general area of Apra Harbor which are also on the National Register.

Waves and Currents

Apra Harbor is relatively well protected from deepwater waves generated west of Guam. However during typhoon conditions and when large western swells from distant storms diffract into the harbor, considerable damage to small and large vessels occurs. The tidal flats and the natural curvature of the Piti Channel protect the channel and general area from these wave effects. A standing wave occurs in the old basin or outfall lagoon area which in all diurnal tidal phases except lower low water has a height ranging from 0.1 to 0.35 feet (MLLW). The period (time from crest to crest) of the standing wave is consistent at approximately 44 minutes. The mean diurnal tidal range is 2.4 feet, with mean sea level at +3.31 feet (MLLW).

There is a dominant westward outflow of water from Upper Piti Channel on both ebb and flood tides. The only tidal reversal occurs on the western half of Tidal Flat D. Warm water from the Cabras Island and Piti power plants moves down Piti Channel, across Tidal Flat C and into the Secondary Channel introducing a warm-surface layer on top of a cooler subsurface layer in the channels. The warm water helps flood the area during rising tides. Another source of flooding water is apparently from a subsurface flow in Piti and Secondary Channels on strongly rising tides. In Upper Piti Channel, currents were measured at an average 0.13 knots in a flood tide and 0.16 knots in an ebb tide. In Lower Piti Channel, the currents were measured from 0.18 to 0.27 knots in a flood tide and 0.39 and 0.47 knots in an ebb tide. The current is even slower than this in the old boat basin.

Water Quality

Guam's updated 1981 Water Quality Standards designate the Commercial Port and Piti Channel area waters M-3 or Fair quality (Figure 9). Specific uses of M-3 designated waters are for: Propogation and sustenance, recreation, aesthetic enjoyment, shipping, commercial and industrial use. The area is also designated as a zone of mixing because of the large volume of water discharged into the area from two power plants. Groundwater in the vicinity of Cabras Island and Piti Channel is highly brackish and has no present uses. Water quality of the Piti Channel area is principally influenced by the combined discharged of 184,000 gallons of condenser cooling water per minute (13.86 cubic meters)

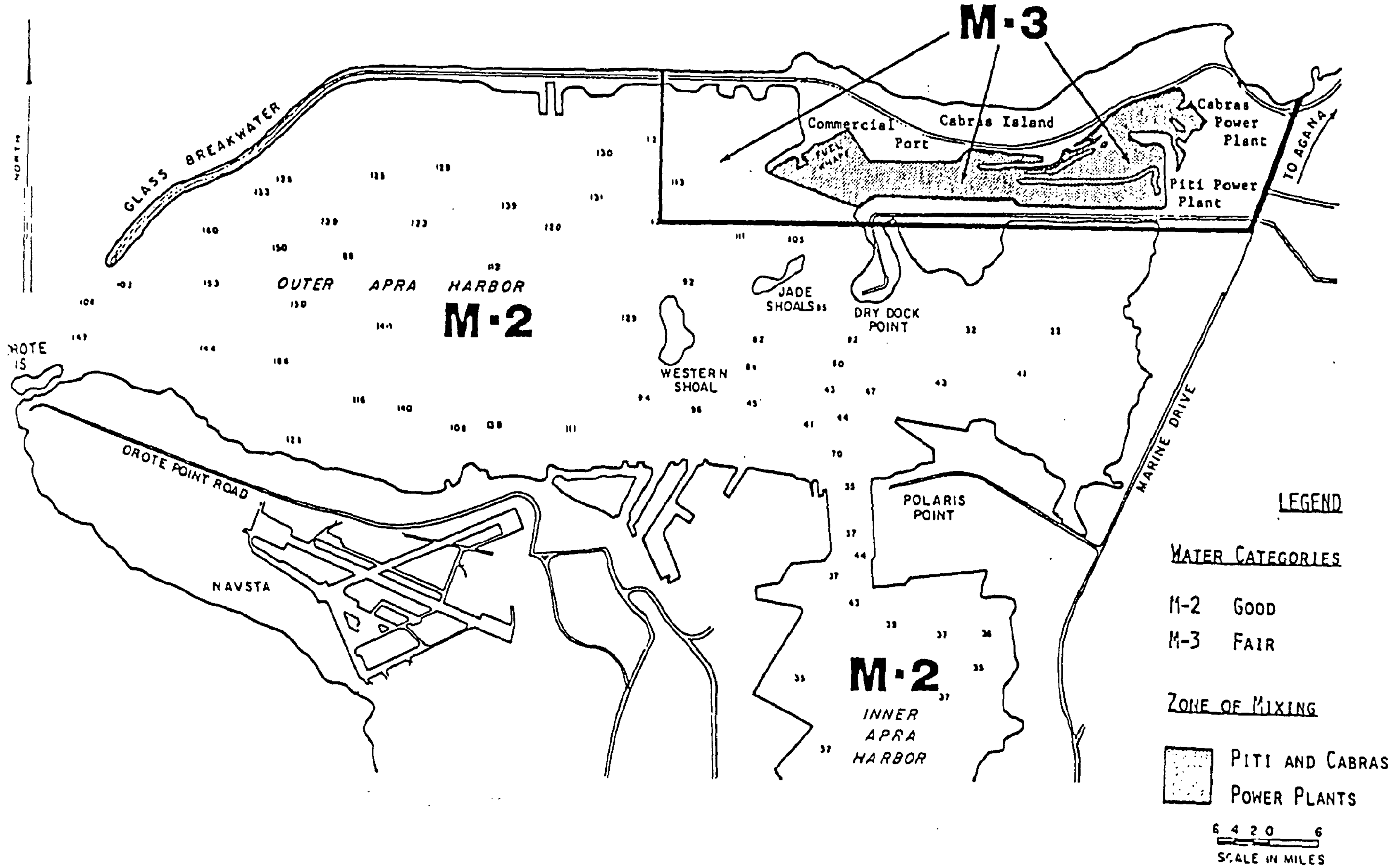


Figure 9: Water Classification and Zone of mixing for Apra Harbor.

from the two power plants at the eastern end of Piti Channel. Oil spills in Apra Harbor proper have little effect in the upper Piti Channel area because of the prevailing current. Drastic habitat modification seems to be a historical element characterizing the marine environment in the Piti Channel area. However, a continuing indicator of good water quality is the historic fishery and the clam beds known to exist in the area.

Water quality measurements in the Piti Channel area were taken continuously between 1973 and 1977. Monitoring was also conducted by the U.S. Navy during late 1977. Analyses of these data indicate that none of Guam's 1981 water quality standards are being violated. Both dissolved oxygen and salinity measurements indicate greater than 100 percent saturation and normal oceanic levels, respectively. Salinity levels do drop significantly in cul-de-sac parts of the moat probably due to surface runoff, but there is little water exchange with the adjacent outfall lagoon. Water in the old boat basin is normally clear. In 1976 there did not appear to be any adverse effects on either the lagoon or the rest of Piti Channel due to the new (1975) discharge of condenser cooling water from Cabras Island Power Plant. The only increased temperature effects appear to be confined to the eastern part of the outfall lagoon adjacent to the point of discharge.

Analysis of the sediments at six sites in 1976 ranging from the upper outfall lagoon (northeast of the proposed mooring basin) westward to Lower Piti Channel indicate the existence of more than trace amounts of heavy metals, particularly iron and aluminum. Although the highest levels of most metals are found immediately in front of the Piti power Plant outfall, the highest levels of chromium and lead was reported at a station just east of the GORCO pipeline in Piti Channel, and a station in the middle of the proposed boat basin has the highest concentrations of copper, cadmium and mercury and the second highest concentration of aluminum. The existence of heavy metals in the Piti Channel area may be a "natural" condition possibly related to the area's former use as a navy dock that it was heavily bombarded during World War II.

Air Quality

Air quality on Guam has been good, and in the Apra Harbor vicinity prevailing winds generally disperse air pollutants out into the open harbor. On Cabras Island, surfaces exposed to the north may be subject to salt spray which coupled with the high humidity and high temperature can create severely corrosive conditions. Construction of two, 200-foot stacks for its five boilers at Piti Power Plant was completed in 1980. New higher stacks solved the problem of down drafts from the old low level stacks, resulting in a much needed improvement in air quality in the vicinity of the plant.

Marine Biological Setting

The marine environment of the Piti Channel area has been as well described as any other place in Guam. Seven studies have been conducted by the University of Guam Marine Laboratory, the U.S. Navy, and The U.S. Fish and Wildlife Service. Updating of these studies was conducted for this investigation. Lists of species and groupings of organisms along given transects and in other sites in the area can be found in the Appendix.

The waters outside the Piti Channel area in Sasa Bay and around Jade Shoals are characterized by rich and diverse species of coral, other benthic organisms and fishes. In Sasa Bay, the abundance of fish eggs and large numbers of juvenile fishes indicates that the area may be an important spawning and nursery grounds. Densities of a few species of clams and oysters suggest a potential for aquaculture. On the slopes of a large, coral-rich patch reef just south of Dry Dock Point is found the coral *Montipora spumosa*, not found elsewhere on Guam. At Jade Shoals, to the southeast of Commercial Port, corals are diverse with 94 species and 39 genera recorded. Various species of *Porites* and *Acropora* are most common and on the deep slopes is the only known occurrence of the coral *Pectinia lactuca*, on Guam. Fish are mainly a diverse group of plankton feeders dominated by *Caesio caerulaureus*.

Occurrence and abundance of organisms in the Piti Channel area was studied in a series of transects beginning at the Piti Plant outfalls and running the entire length of the channel to the Commercial Port. Two groupings of organisms were recognized. The first consisted of the red alga *Gracilaria salicornia* and the brown alga *Padina tenuis* which are particularly abundant in the lagoon area immediately adjacent to the Piti Outfall. The second grouping consists of more widely occurring species common throughout the length of the Piti Channel, including the calcareous green alga *Halimeda opuntia*, a shrimp-goby burrow association, sand cones probably created by an unknown species of polychaete worm, the sponge _Spirastrella vagabunda_, a red algal mat composed primarily of _Hypnea esperi_ and _Champia_ sp, the seagrass _Halophila minor_, the sea cucumber _Bohadschia bivittata_ and massive corals of the genus _Porites_.

The sand-bottomed area of the old boat basin is characterized by burrowing organisms which have built large cones of sediment excavated from their burrows. The continual reworking of the sediments keeps the bottom in flux and probably is a major factor in determining the nature of the benthic community as a whole. The epibenthic flora consists of a cover of filamentous red algae (_Hypnea esperi_ and _Champia_ sp.) which forms mats and provide food for the strombid gastropods _Strombus luhuana_ and _Lambis lambis_. The sedentary medusa _Cassiopeia_ sp. has been seen in this area. Two deep areas were dredged out along the southern shore to provide dry-docking facilities used when the area was a fishing port in past years. Relic live colonies of _Porites lutea_ occur in the western-most (deeper) of these two areas and scattered around its margin. Since reported in 1976, these corals have decreased in abundance according to observations made earlier confirmed in 1984 by this study. Transplanted _Porites lutea_ coral continued to survive, although with difficulty, at three artificial reef stations; however U.S. Fish and Wildlife Service observations in 1979 failed to locate any live coral in Piti Channel. Best survival, as of 1977, was at a station about 200-250 feet upstream (northeast) of the proposed boat basin. Intermediate survival occurred at a station near the mouth of Lower Piti

Channel and poorest survival occurred at a station in Upper Piti Channel. West of the Cabras Island Power Plant outfall on the northwestern side of the proposed boat basin there are scattered patches of the brown alga Padina tenuis and the seagrass Halophila minor.

The sand and coral rubble tidal flats B and C (Figure 4) adjacent to Piti Channel are characterized by an abundance of the sponge Spirastrella vagabunda. The brown alga Padina tenuis, the red alga Gracilaria salicornia, the seagrasses Halophila minor and Enhalus acoroides, the crabs Carpilius maculatus, Calappa hepatica, and Clibanorius striolatus and numerous species of molluscs are also found there. According to the US Fish and Wildlife Service in 1977, the most common mollusk is Littorina scabra. An abundance of Cerithium sp. are found on Tidal Flat D. The most biologically diverse and significant area in the Piti Channel area is a patch reef at the southeast corner of Lower Piti Channel. Nearly 21 percent of the substratum was under coral growth in 1977, and the unique coral species Pavona frondifera dominated the patch reef area with a relative coverage of 95 percent compared to other coral species. In 1977, it was discovered that all species of coral at the patch reef area were in a state of stress or already killed. No cause of the condition was identified. Fourteen colonies of the coral Pavona frondifera were transplanted to Western Shoals in Apra Harbor. As of January 1979, part of the transplanted coral colonies were still alive. The next most biologically diverse areas are the portion of the outfall lagoon immediately adjacent to the Piti Power Plant outfalls and the Lower Piti Channel downstream of the GORCO pipeline.

Fish surveys conducted in the Piti Channel and Commercial Port area in 1977 indicated low to moderate species diversity and generally low abundance except near the west end of Piti Channel where numerous adult and juvenile cardinalfish (apogonids) and damselfish (pomacentrids) were observed. Dominant species of fish in the outfall lagoon include various surgeonfishes (acanthurids), cardinalfishes (apogonids), gobies (gobiids), snappers (lutjanids), angelfish (pomacentrids), and parrotfish (scarids). Based on two series of zooplankton tows conducted in 1976, crab and shrimp larvae and fish eggs were found in consistently high abundance in the Piti Channel and the outfall lagoon area, while gastropods, Lucifer, copepods, pteropods, and larvaceans are abundant in Commercial Port waters. Analysis of the density of individual plankters showed that the Commercial Port waters were the richest followed by those in the Upper Piti Channel area. The relatively high number of fish eggs found in these areas also suggest they may be spawning grounds for a number of marine fishes. No threatened or endangered species of marine organisms are found in the Piti Channel area.

Terrestrial Environmental Setting

The heavily modified land areas in Apra Harbor are characterized by secondary shrubby and shrub forest growth dominated by tangan-tangan (Leucaena leucocephala) and ironwood (Casuarina) on Cabras Island, Drydock Peninsula and the islets in Piti Channel. Bordering the eastern shore of Apra Harbor from

Upper Piti Channel south to Polaris Point is the largest and most productive mangrove association in Guam dominated by Rhizophora and Avicennia species.

The U.S. Fish and Wildlife Service reported in 1978 and 1979 that 23 resident and migratory bird species could be found around Apra Harbor. Ten of these species were observed flying over or feeding in the Piti Channel area. The islets in the Piti Channel area provide feeding habitat for common varieties of migratory shorebirds. No resident species of birds proposed for listing as endangered (E) or threatened (T) have been observed feeding in the study area, but the Chinese Least Bittern (T), Guam Rail (T), White Tern (E), and Micronesian Kingfisher (E) were observed in January 1979 flying over the Piti Channel area. Other wildlife species such as the introduced brown tree snake, native monitor lizard, fruit bat, and hawksbill and green sea turtles have been reported in the general Apra Harbor region. Only the monitor lizard and green sea turtles are common around Apra Harbor and might be found occasionally in the Piti Channel area. The green sea turtle (Chelonia mydas) was listed under Federal threatened status in August 1978. According to the U.S. Fish and Wildlife Service, special effort should be directed toward preserving habitats, such as mangrove wetland, reef flats, seaweed beds and islets that could be utilized by the Guam Rail, Reef Egret, Chinese Least Bittern, White Tern, Marianas Fruit Dove, and green sea turtle. All these species are included in the preliminary and unofficial Guam endangered and threatened species list. Based on existing information, the Piti Channel area is not considered important or potential critical habitat for any of these species, and based on the types of industrial activities conducted there (shipping and power production), it is likely that the area is only a marginal habitat at best.

III. SUMMARY OF ACTIVITIES

A. COAL AS AN ALTERNATE FUEL

Proposed use of coal as fuel for the Cabras steam power plant does not contemplate conversion of the existing boilers from oil to coal firing. Since the plant was not designed for coal firing, such conversion would be quite impracticable. An addition to the existing plant consisting of coal fired boilers with steam headers to the existing turbines would be provided. Thus Cabras could burn either coal or oil in event of a fuel shortage or alternate for boiler maintenance.

B. SOURCE OF COAL AND SHIPPING REQUIREMENTS

Coal would be transported from Australia Bowen Coal Basin in Queensland, or other Australian source. Currently colliers of 50,000 DWT and less are readily available and would serve quite well initially in the delivery of coal from Australia. This is related not only to the availability of the colliers, but to the inventory cost of stockpiling large shipments and cost of handling. However, Panamax class self-unloading colliers between 50,000 and 60,000 DWT would eventually be used to transport the coal from its origin. Turnaround time per ship would be 10 days. Approximately 328,000 tons of coal is needed for a three month contingency including 5% loss for weathering, handling and moisture. Based on this volume, seven collier trips will be required per annum to maintain the three month reserve.

C. COAL HANDLING UPON ARRIVAL AT APRA HARBOR

Collier Off-loading

Wharf space for docking a collier is not available in Apra harbor. The possibility of such a development falls far short of economical justification at this time. Therefore, it is proposed that the coal be barged from collier anchorage in Apra Harbor to a wharf adjacent to the coal storage yard near the Cabras power plant. The existing Piti Channel needs to be dredged to permit passage of barges for off-loading at a new wharf near the storage yard.

Barge Off-loading

Barge operation would be coordinated with the off-loading rate of the collier. Thus payment of per diem for delay in off-loading would be avoided. Preliminary studies indicate that off-loading within the allowable free time can be accomplished with 4,000 DWT barges, towed by tugs. Note that tugs would be free for other uses between shipments of coal.

Storage Yard

Coal in compact storage would weigh about 50 lbs per cu ft. Thus one ton would occupy approximately 40 cu ft. With a 3-month backlog for contingencies, coal stacked 24 ft high with a 2 to 1 slope would occupy an area approximately 500 ft. in length and width. This is based on 50,000 tons per collier delivery including a 3 month backlog and 30% for variance in coal delivery. This could be cut down in proportion to both variances and reserve held for contingencies. Also the area for coal storage could be reduced by stacking to heights of 30 or 40 ft.

Dust Suppression

Coal dust can be contained before it becomes airborne by means of a relatively simple spray system that utilizes a surface active compound dissolved in water. The amount of film needed for effective dust control is so small that less than 1% of its total moisture is usually quite sufficient.

Weather Protection

Coal can be conveniently weather protected by means of a polyvinyl cover held in place by sand bag weights.

D. COAL HANDLING FROM STORAGE YARD TO BURNERS

At the Cabras Wharf coal will be off-loaded by a clam shell gantry crane and then conveyed to the stacker. A bulldozer will level and compact the coal for storage. The stored coal is conveyed to the coal crushers near the boiler house by means of a reclaimer and conveyor. From the crusher the coal is conveyed to the raw coal bunkers in the boiler house. Flow of coal to pulverizer and burners is shown in Figure 10.

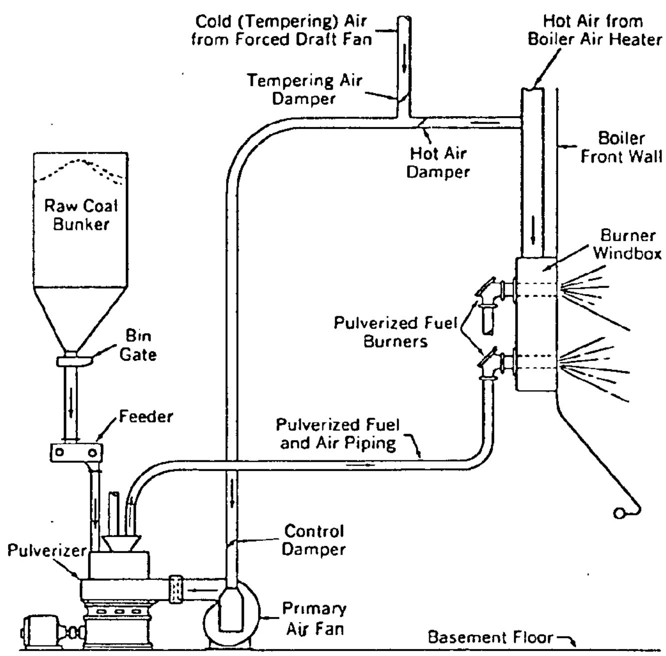


Figure 10: Direct-firing system for pulverized coal. (From Vopat and Skrotzki, 1960)

IV. LAND USE RELATIONSHIPS

A. FEDERAL GOVERNMENT PLANS

There has been much concern over the years regarding commercial development in the vicinity of Cabras Island. The biggest hurdle to overcome is the relocation of the Navy's Ammunition Wharf. Taking precedence over existing or future land use plans is the restriction placed upon land use by the Explosives Safety Quantity Distance (ESQD) which is a circular zone the U.S. Navy placed around the ammunition wharf on the Glass Breakwater (Figure 11). This distance was originally 10,400 feet, but was reduced 20 percent in 1977 to 7,210 feet. Until the ammunition wharf is relocated or unless other arrangements are made with the U.S. Navy, no permanent facilities will be permitted to be constructed within the perimeter of the ESQD. Plans are to relocate the Ammunition Wharf to Orote Point where the ESQD will not interfere with Commercial Port development.

Congress has appropriated funds for the relocation project and bids are to be solicited during the last quarter of 1984. Assuming a contractor is awarded the contract, construction should begin in early 1985.

According to Government of Guam sources, a total of 927 acres of land on Cabras Island is held by the U.S. Navy. At this time only 33 acres on Cabras Island are held by the Government of Guam. The remaining land owned by the Navy will remain under its control until after relocation of the Ammunition Wharf. According to the Navy's Guam Land-use Plan, all remaining portions of Cabras Island (excluding

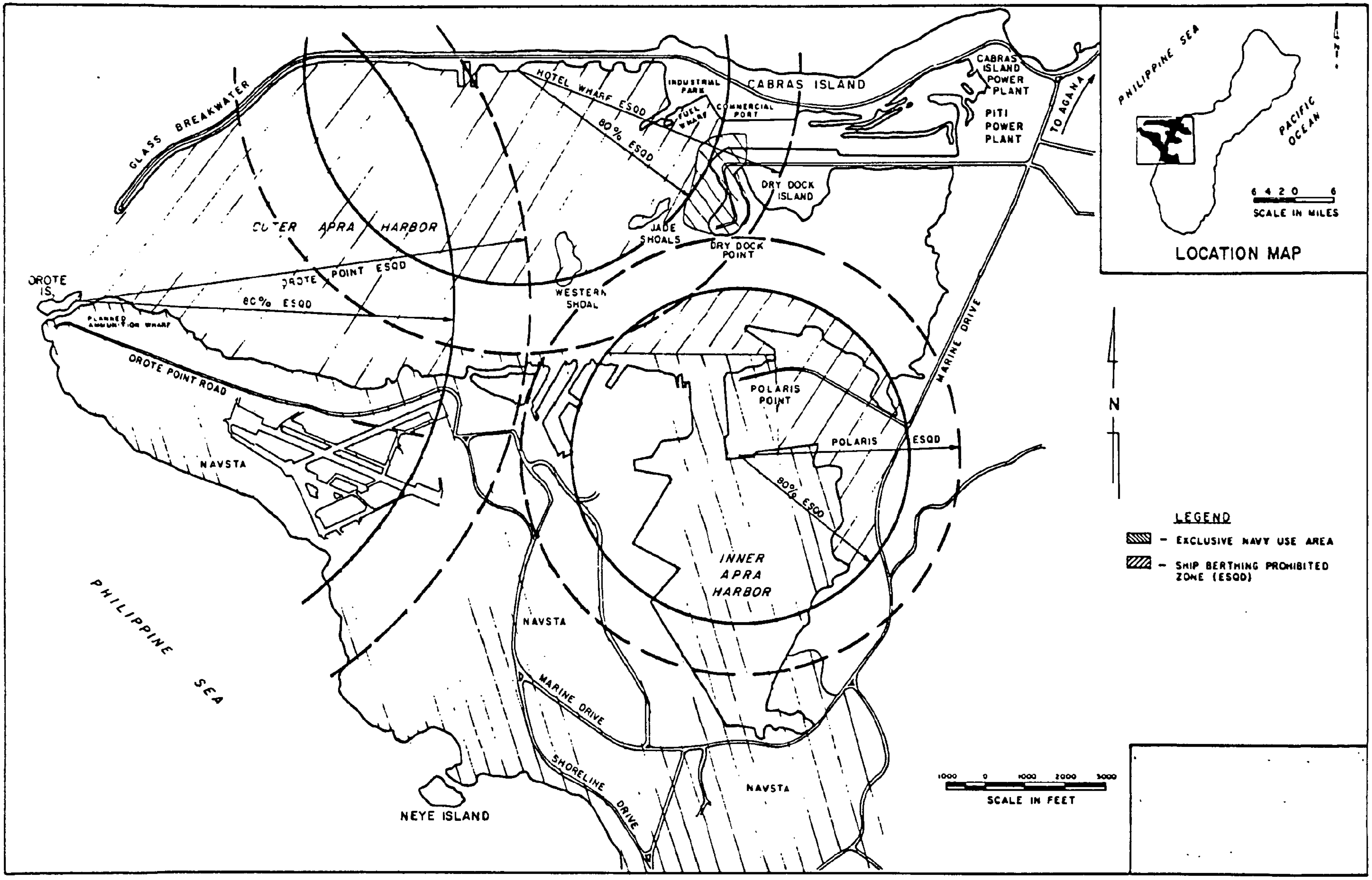


Figure 11: Explosive Safety Quantity Distance in relationship to existing and proposed ammunition wharf in Apra Harbor, Guam.

the western part of the Glass Breakwater) will then be released for expansion of the Commercial Port and related industrial activities.

Although Navy owned land will be transferred to the Government of Guam, any revenue derived from leases by the local government will belong to the Federal government.

The Navy proposes a three phased approach for the transfer of 927 acres of federally owned property to the Government of Guam.

<u>Phase I</u>

571 acres to be immediately conveyed as follows:
- 298 acres fast land
- 273 acres submerged land

<u>Phase II</u>

321 acres to be conveyed upon relocation of Ammunition Wharf as follows:
- 73 acres leasable now
- 233 acres submerged land
- 15 acres held until all Navy activity ends in the wharf area

<u>Phase III</u>

35 acres will be held until no further military requirements are needed in the area.

B. GOVERNMENT OF GUAM PLANS

The Government of Guam has focused its attention to improving Port related activities in the vicinity of Cabras Island. A major obstacle to overcome has been the acquisition of Navy owned land in Cabras Island and the relocation of the Navy's Ammunition wharf as explained earlier. These entities have been underway for some time and with the relocation of the Ammunition Wharf this problem should be solved in the near future.

Recently a number of studies have been prepared to identify the need for improving Port facilities and direction the Port should take to meet future needs in regards to shipping.

In 1978 the Government of Guam, Division of Planning finalized its Comprehension Development plan which included a Land-use and Community Development Plans 1977-2000. In July 1979 the Economic and Land-use Plan for Cabras Island and surrounding area was prepared jointly by the Port Authority of Guam and the Cabras Island Task Force. The Task Force was organized by then Governor Calvo and consisted of members from the Bureau of Planning, Dept. of Commerce, GEDA, Guam Growth Council and members of the Port Authority of Guam Advisory Council. In 1981 the Port Authority of Guam completed the Commercial Port of Guam Master Plan. It is emphasized that the Port Authority's plan is compatible with other plans and land-use standards designated in the Bureau of Planning land-use plan, Guam 1977-2000 in that the ecological concerns of the plan are being adhered to. The following assumptions were made in the Ports Master Plan:

1. Port facilities must be developed sufficiently to accommodate current traffic needs and expected increases in future years.
2. The Port Authority will coordinate the planning and prioritization of water-oriented activities to be located around Apra Harbor in order to minimize any adverse impact upon port operations.
3. The multiple use of Apra Harbor for shipping, industry recreation, conservation and defense is beneficial for all concerned.
4. Waivers from the ESQD Zone requirements can be obtained from the Navy for lands which fall between the existing 7,210 ft zone and the preferred 10,400 foot zone for the ammunition wharf. However, the Ammunition Wharf should be relocated soon.
5. Military lands not released in 1980 but which are required for Port development will ultimately be acquired by the Government of Guam.
6. The Navy's Hotel Wharf (site of the present Ammunition Wharf) will be available to the Commercial Port for use by passenger ships and fishing vessels when not in use by the Navy.

Since these objectives were set improvements to Port operations have been noticed. In 1982 an 11 acre site for the enlargement of the container yard facility was completed. In conjunction with this project, a portion of Route 11 was realized improved as was lighting for the yard. A second Gantry crane was put into operation along the wharf in 1982. This improved loading and unloading considerably. The Army Corps of Engineers completed their Harbor of Refuge Detailed Project Report and Environmental Statement in 1979. At this time an Addendum to this report is being prepared by the Port Authority of Guam for one additional alternative site. This study should be available for review by September, 1984.

C. CONFORMITY AND CONFLICT OF PLANS

The Federal and local government have been working together for many years to resolve the conflict between land use in the Commercial Port/Cabras island area. For the most part, conflicts should be virtually eliminated once the Ammunition Wharf is relocated. At that time Navy land should be transferred to the Government of Guam and development of the area can proceed.

Conflicting with the official Government of Guam Land-use Plan and Navy Land-use Plan for Guam, is the Program for Development of Apra Harbor prepared for GEDA in 1977 which presumed that all but the western portion of Drydock Peninsula will be available for industrial development. The southern shore of Cabras Island and the Piti Channel area would remain generally undeveloped, but Tidal Flat D would be dredged and transformed into a recreational boating area and the central portion of Drydock Peninsula would be fully developed into a fish processing and docking facility, including extensive dredging in Sasa Bay. The eastern inner shoreland of Sasa Bay, presently in mangroves, would be developed into a large industrial park.

Besides this coal conversion project, another project will require extensive dredging of at least the upper Piti Channel. The Harbor of Refuge project, currently being studied by the Port Authority of Guam, will require dredging of the Piti Channel as an aid to navigation as well as the refuge basin to be located in the eastern corner of Tidal Flat C. Coordination between these two projects is essential to ensure that the proper width and depth of the channel be dredged at one time minimizing environmental impacts in the general area.

V. GENERAL IMPACTS OF THE PROPOSED ACTION ON THE ENVIRONMENT

A. ENVIRONMENTAL ISSUES IN THE TRANSPORT AND HANDLING OF COAL

INTRODUCTION

Coal as a Pollutant

There are a number of environmental factors to be considered in the transport, handling and stockpiling of coal. In particular, attention should be given to the problems of coal spillage, generation of airborne dust, spontaneous combustion and rain water runoff which may carry coal dust into waterways and harbors.

As a bulk material, coal must be handled many times between its point of extraction at the mine, and the ultimate point of combustion in a power station. Each transfer point in that transport and handling system is a potential source of pollution and indiscriminate use of the conveying or transport equipment could distribute the coal dust over a wide area.

The increasing requirement for coal as an energy source is resulting in larger and greater numbers of coal storage facilities. As the size of most facilities will require the use of open stockpiles, careful attention must be given to the design of these facilities to minimize the generation of airborne dust from the exposed surface.

The increasing importance placed on the value of environmental management creates a requirement to achieve a proper balance between resource development and maintenance of environmental quality.
This balance is generally being achieved at the coal mines, power stations, cement works, port facilities, and other facilities which are handling large quantities of coal. Mistakes have been made in the past,

resulting in adverse environmental impacts. Research during the last ten years has resulted in the development of pollution control methods which currently provide a high degree of control at an acceptable level of cost.

Environmental Planning and Control

The control systems necessary for mines and other facilities located away from cities and towns will, of course, be far less sophisticated than will be the case of coal handling facilities located in densely populated areas.

The selection of the appropriate control measures calls for balanced judgement based on a sound knowledge of the particular facility, the environment affected and a realistic appreciation of the true community need. Many governments ensure that an even-handed approach is achieved by having an environmental control organization which controls the planning and operation of facilities. The environmental protection responsibility lies with the Guam Environmental Protection Agency (GEPA), which monitors the quality of air emissions in relationship to power generating facilities such as the Cabras Power Plant. GEPA will have a role in the final planning of such a facility.

Meteorological Data

When considering the systems which have been developed for pollution control it is important to consider that weather conditions differ in some areas. It is therefore important to obtain the fullest possible meteorological data for the proposed site.

Environmental Factors

Environmental authorities may require that consideration be given to a number of factors which include the following:

a. air pollution

b. water pollution

c. noise pollution

d. visual impact of stockpiles and facilities

e. effect on flora and fauna

f. effectiveness of land use

1. TRANSPORT SYSTEMS AND THE ENVIRONMENT

Transport Options

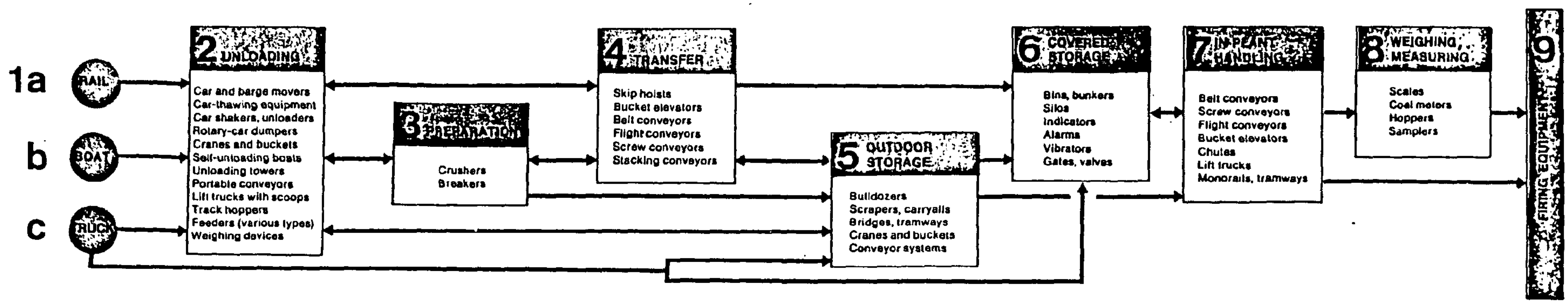
Once a vessel has been loaded and the hatch covers fixed in place, there is normally no environmental problem caused by the spillage of coal (Figure 12). The problems associated with loading and unloading will be discussed briefly in this section. Problems would normally only occur during loading or unloading even for barges.

Shiploading and Unloading

A typical shiploading facility is shown in Figure 13. Provided the shipping conveyors and the boom conveyor are totally enclosed, there is very little likelihood of spillage or airborne dust being generated.

The telescoping spout at the end of the boom can be used to discharge coal into the hold of the vessel without causing any significant dust nuisance.

The intermittent type ship unloader shown in Figure 14, suffers from the disadvantage that the grab bucket must be moved from the hold of the vessel into a receival hopper on the wharf side. During the movement of the bucket, coal dust can be spilled, causing airborne dust pollution and spillage onto the wharf.



Receiving, unloading

The unloading system depends mainly on the way coal arrives at the plant. Some forms of shipping—for example, barges—cannot self-unload at all, so unloading equipment is an absolute necessity. Other types of vehicles, like hopper cars, can self-unload, but equipment (such as dumpers, thawers, shakers, etc) often is installed to speed the job or to make it easier under adverse conditions. Frequently, devices such as feeders are added to set up a controlled flow to the next step in the handling process.

Preparation, transfer

If coal is bought unsized, and sizing is desirable for storage or firing, preparation may be done near the receiving point, as diagrammed above, or in-plant near the point of use.

Transfer refers to handling between the unloading point and the final storage point, from which coal normally discharges to the firing equipment. It may involve only one piece of equipment, or several, depending on local conditions and whether there is more than one storage point in the system.

Storage

Since it generally is not practical to deliver fuel at the rate it is burned, coal is stored at the plant site in quantity. This permits you to minimize shipments and to iron out variations in delivery. Storage may be outdoors or under cover—either in a silo or similar outside structure, or in bins or bunkers in the plant. It is common practice to have a relatively small storage area to cover normal needs, and a larger one (often outdoors) for reserve, with means for transferring from dead to live storage.

In-plant handling

In-plant handling refers to the movement of coal between final storage and the firing equipment. In simple systems, this can mean no more than chutes that direct flow to individual firing units, and gates or valves to control flow. Larger plants might have a conveying system to feed coal from any bunker section to any firing unit, and to move coal from one bunker section to another. Weighing or measuring may be done near firing units, at the receiving point, or at both locations.

Figure 12: Receiving, Unloading, Preparation, Transfer, Storage and In-plant handling of coal flow chart. (From Power, A Special Report, February 1974)

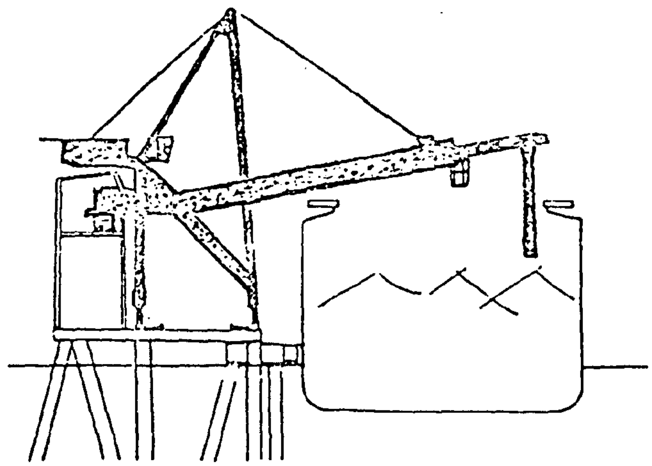


Figure 13: Shiploader.
(Figure 13-15 from United Nations, ESCAP Vol. 1, 1982)

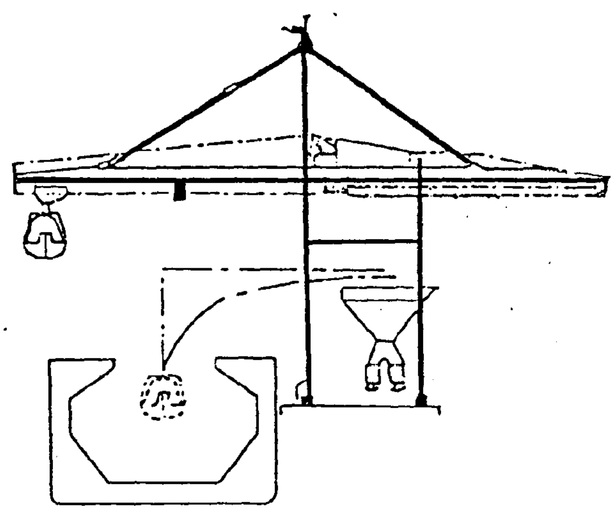


Figure 14: Intermittent type ship unloader.

Any spillage occurring on the wharf should be picked up by front end loader or should be hosed down into collecting sumps for subsequent disposal, before contamination of the waterway occurs.

The continuous type of ship unloader, as shown in Figure 15, offers much greater control over spillage and airborne dust.

The amount of airborne dust generated can be reduced to some extent by the application of a dust suppressant prior to export. Chemical treatment is described later. Japanese importers have reported that coal treated in this manner has helped to reduce dustiness on arrival in Japanese ports.

2. BELT CONVEYORS AND POLLUTION CONTROL

Enclosure

Although most belt conveyors at mine sites are not enclosed, it is good practice to fully enclose belt conveyors operating close to areas where airborne dust may be a problem. However, even in sensitive areas, stockyard conveyors cannot be enclosed because of the requirements of stockyard machines. Such conveyors should be generously sized to minimize spillage in this case.

Transfer Points

When coal is discharged from the head pulley to a following conveyor, it is airborne for some seconds until the flow settles on the following conveyor. During the period when the stream is airborne cross ventilation can carry dust into the environment. It is therefore desirable that transfer chutes be designed to provide an effective enclosure around the stream of coal. Dust suppressant sprays are sometimes provided at the transfer points.

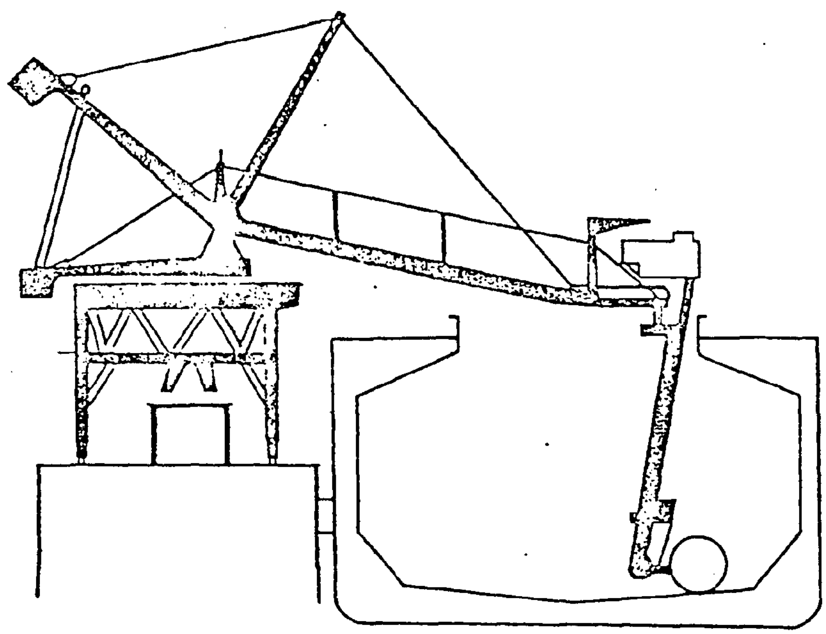


Figure 15: Continuous type ship unloader.

Design of transfer points has to include a suitable compromise between enclosure, impact wear of chute surfaces and smooth flow of material to prevent blockages and spillage.

Belt Cleaning

Many devices have been designed to remove scrapings from the return face of conveyor belts. Many of these in the past have been ineffective and have allowed material to travel along the return strand of the belt until it falls to the ground underneath the conveyor. Recently, more effective scraping devices have been developed, but it is important that the scrapings be redirected back into the coal flow before building to an excessive level.

Belt turnovers have been extensively used, applying a system which rotates the return strand of the belt through 180° so that the dirty side travels upwards until the belt arrives at the tail end of the conveyor where it is returned to its original position for passing around the tail pulley. Some secondary problems with belt turnovers have reduced their popularity due to problems with their operation. The concurrent development of more effective scraping devices has also contributed to more widespread use.

High labor costs involved in spillage collection have encouraged the use of more effective scraping devices.

Hosing Down

It is inevitable that some spillage will occur and an effective means of spillage control employs water applied as a jet to gantry floors. The spillage is washed into a sump where the material is collected prior to disposal.

Noise Control

Excessive noise is not often a problem with coal handling facilities. However, effective noise control can be achieved when necessary by adopting the following:

a. Enclosure of above ground conveyors

b. Enclosure of all drives

c. Impact curtains can be installed where necessary at transfer points

d. Sealing of conveyor apertures with lead impregnated fiberglass cloth

e. Silencers on ventilation openings

f. Concrete and masonry construction of transfer houses for noise control

In highly critical areas, conveyors have been located below ground level and have been fitted with acoustically treated ventilation paths. This effectively eliminates all noise emission from the conveyor.

3. STORAGE SYSTEMS

Storage options

The relatively high cost of fully enclosed storage units such as silos, bins and bunkers dictates that they are mainly suitable for small volumes. Because of the relatively low cost of open stockpile storage, and the fact that coal normally does not deteriorate with exposure to the elements, open stockpiles are preferred for coal storage at facilities such as power stations and ports.

The comparative cost of different types of storage is illustrated in Figure 16.

The relative economy of open stockpiles, combined with the need for very large volumes, has encouraged the development of pollution

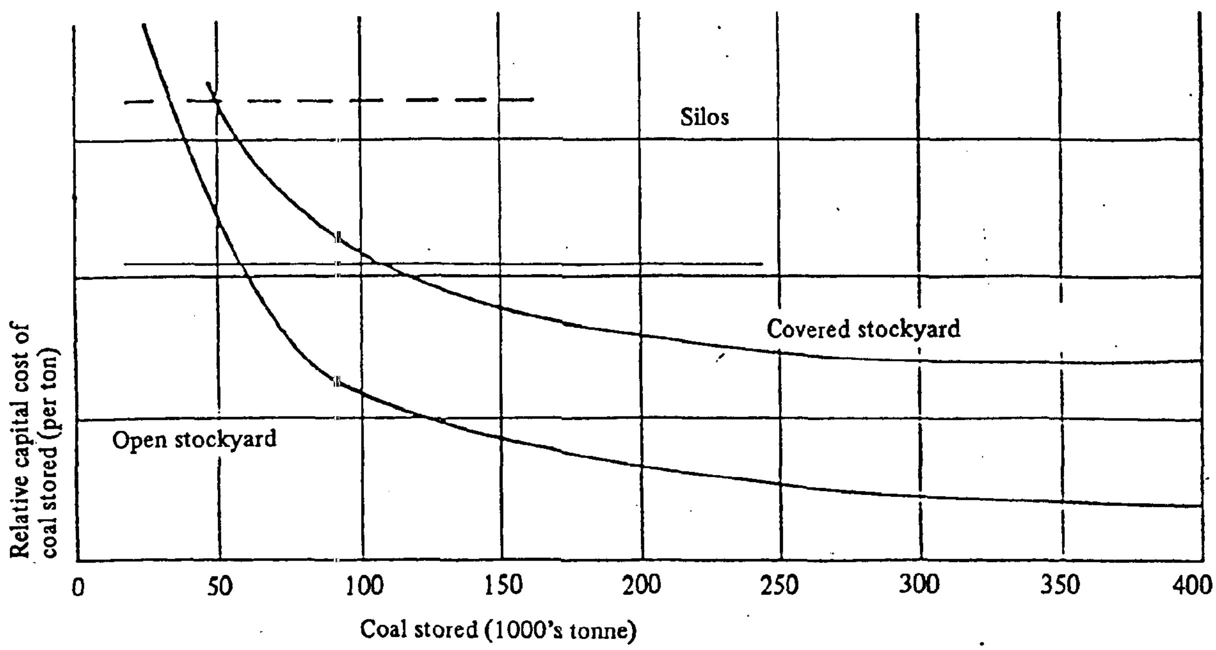


Figure 16: Comparative cost of storage.
(From United Nations, ESCAP Vol. 1, 1982)

control methods which minimize the problems of air and water pollution. Dust suppression techniques are described later.

Stockpile Drainage

Some stockpiles are subject to periods of very heavy rainfall, as is the case on Guam. Stockyards are therefore graded to surface drains which transfer rain water into a settling pond before being discharged into waterways or harbors.

The settling ponds may also receive the discharge from sewage treatment plants connected with the facilities and coal separation plants associated with hosedown and belt cleaning activities in addition to rain-water runoff from stockpiles, roads and buildings. Additional treatment, discharge through chemical dosing plants, may be necessary to maintain effluent limits set by the Guam Environmental Protection Agency. An effective drainage system can also help to reduce the problems of moisture content in coal.

Instability of coal stockpiles during heavy continuous rainfall, on the order of 15cm (approximately 6 inches) in 24 hours, may occur. Slope failures vary from local slumping to coal flows which extend distances of up to 60 meters (approximately 197 ft) from the base of the pile. Although slumps can be cleaned up relatively quickly, this occurrence should be avoided where possible. Measures which can reduce this occurrence include effective drainage, compaction at the base of the stockpile and covering of long term storage with bitumen coating.

Stockpile Orientation

Where it was possible to select the physical orientation of the stockpiles, running the axis of the stockpiles in the same direction as the prevailing winds helps control environmental pollution problems.

However, with the installation of water sprays it has been found desirable to orient the axis in a direction perpendicular to the prevailing winds. This latter arrangement has the advantage that the wind can be used to assist dispersion of mist from water sprays.

Stacking and Reclaiming

Stackers (Figure 17) should be operated with the boom close to the stockpile surface. Ideally, the discharge should not drop more than 1-2m to minimize the effect of air movement carrying dust from the descending coal stream.

The digging action of bucketwheels or reclaimers (Figure 18) can generate dust. This dust generation can be minimized by the application of water sprays above the bucketwheel. However, such an installation requires a continuing flow of water which must be supplied from a trough or a tanker trailer. Chemical treatment methods have been found to entirely eliminate the need for water sprays in the vicinity of the bucketwheel and at the boom of stackers.

4. DUST SUPPRESSION SYSTEMS

Introduction

Many methods have been used to suppress or remove coal dust generated during handling operations. Some are designed to control dust during loading, unloading, conveying, transfer, stacking and reclaiming operations. Others have been developed for control of emissions from open air stockpile surfaces under windy conditions. The main systems currently in use are reviewed here.

Dust Extraction Systems

A dust extraction system is a well-established method for the containment of generated dust and has been used in many applications.

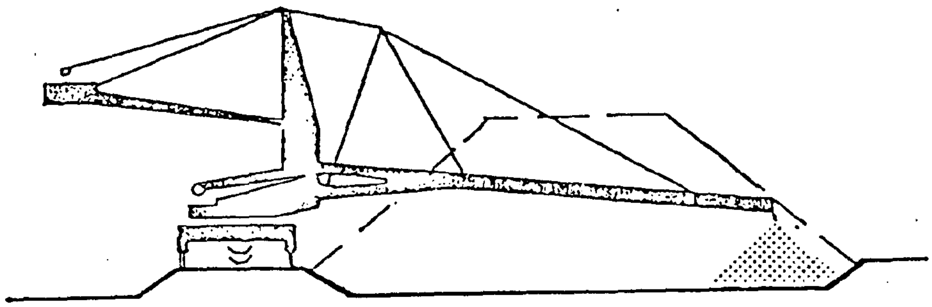


Figure 17: Slewing boom stacker.
(Figures 17 & 18 from United Nations, ESCAP Vol. 1, 1982)

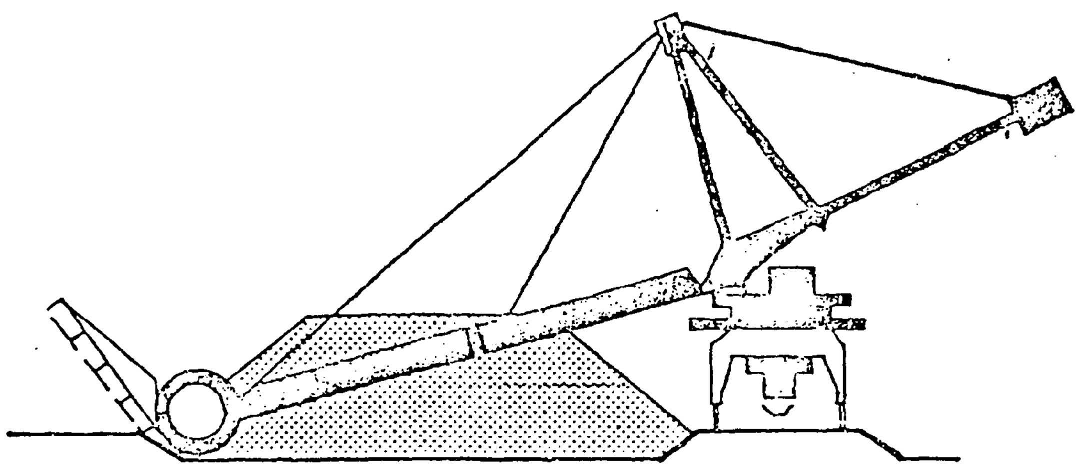


Figure 18: Bucket wheel reclaimer.

Its use in coal handling plants is limited to areas where complete enclosure can be provided. Applications include:

a. the top of bins and hoppers

b. conveyor transfers

c. bin and chute discharges

d. bucket wheel reclaimers

e. ship unloaders.

The use of this method dictates that an efficient dust filtration plant and dust disposal system be incorporated. Physical size of air extraction ductwork and power requirements of dust transport result in centralized filtration plants being impractical. Hence, multiple installations are necessary throughout a coal handling plant. This type of system generally has a substantially higher power requirement than wet-type systems.

Surfactant Dust Suppression Systems

The incorporation of multiple water spray stations throughout the conveying system at all belt transfers and feeders is a well established method of dust control. Each spray station includes a proportioning plant which adds a small amount of a wetting agent to the water to overcome the hydrophobic nature of the coal and ensure effective re-absorption of the added moisture. This method of dust suppression is only effective while the moisture level is maintained above the dustiness threshold of the particular coal being transported.

Chemical Total Treatment Systems

It has long been established that wet coal is not dusty. Uniform drying-down results in a threshold level being reached at which fugitive dust is released. Further drying increases the dust release potential of the coal.

For some years the addition of water to dry coal to decrease the potential of dust release has been common practice in coal handling plants. Problems associated with this method include:

a. the hydrophobic nature of coal prevents effective re-absorption of moisture.

b. the non-uniform, re-evaporation loss of added moisture dictates the need for regular water additions throughout the handling plant.

c. the shipping cost penalties of accumulated excess moisture in the coal.

The use of wetting agents designed to break down the surface tension of water and improve re-absorption of moisture by the coal, has largely overcome the first problem but the other two persist.

The potential of total treatment of the coal stream to reduce its dust release levels was explored seriously early in 1974 and intensive research and development has led to the successful implementation of this method. The objective was to develop a technique which would allow the use of one or two initial treatments of the coal at or near the point of receival to achieve complete control of dust emission levels throughout the handling plant. This approach simplified the design, operation and maintenance requirements for dust suppression systems within the coal handling facility. It also yielded other benefits such as:

a. reduced overall moisture addition compared to other wet-type systems

b. stockpile surface crust formation improvement

c. residual dust control evident at point of receival overseas.

The salient features of this system are discussed briefly:

a. Chemical Selection

The primary task is the selection of chemicals which display an ability under laboratory test conditions to substantially reduce the dust release potential of the coals to be handled.

This test work is undertaken with coals considered to be representative of those to be handled through the facility. The cost effectiveness of different chemicals and variations in concentration and application levels are evaluated (Figure 19).

b. Proportioning Plant

Design of the proportioning plant is based on the results of laboratory and field tests. Where a wide range of coal types are to be handled, the plant can be designed to allow treatment to be varied from one coal to another.

Reliability is an important factor since it is essential that all coal be treated at this point. No other treatment facilities are provided in the plant. For this reason, critical elements of the plant such as pumps, flow controllers, metering equipment and controls are duplicated.

c. Spray Stations

It is essential that the treatment be applied to the coal stream at a location where maximum penetration can be achieved. High pressure atomising sprays are used for optimum dispersion of the treatment. Suitable locations for sprays include vibratory feeder discharges and conveyor transfers.

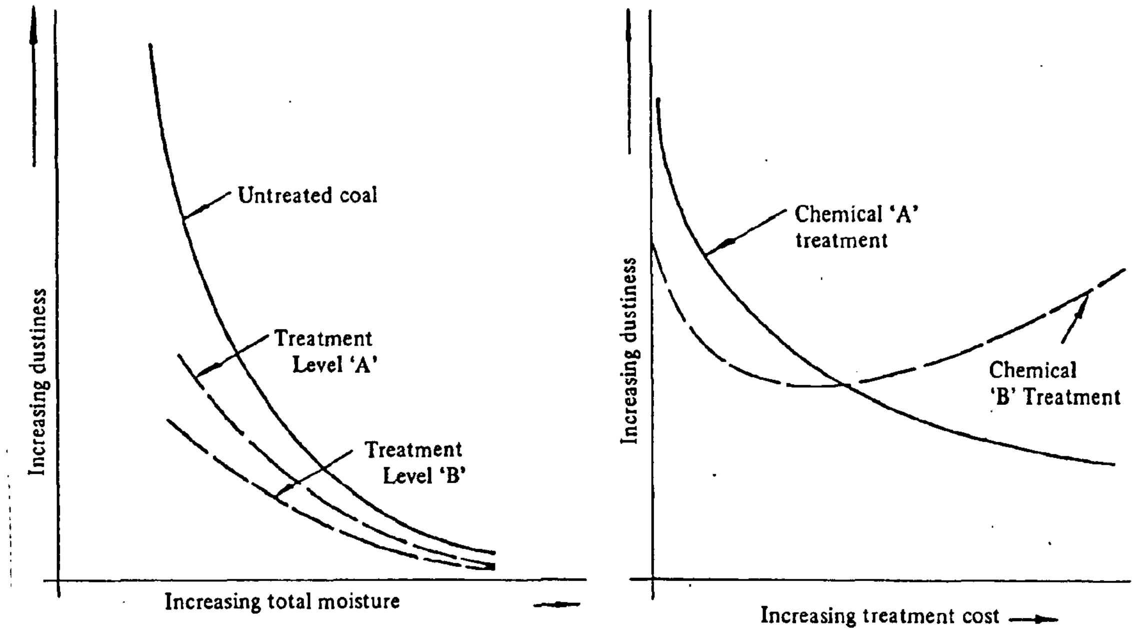


Figure 19: Typical dynamic dust control characteristics of coal with chemical total treatment.
(Figures 19 & 20 from United Nations, ESCAP Vol. 1, 1982)

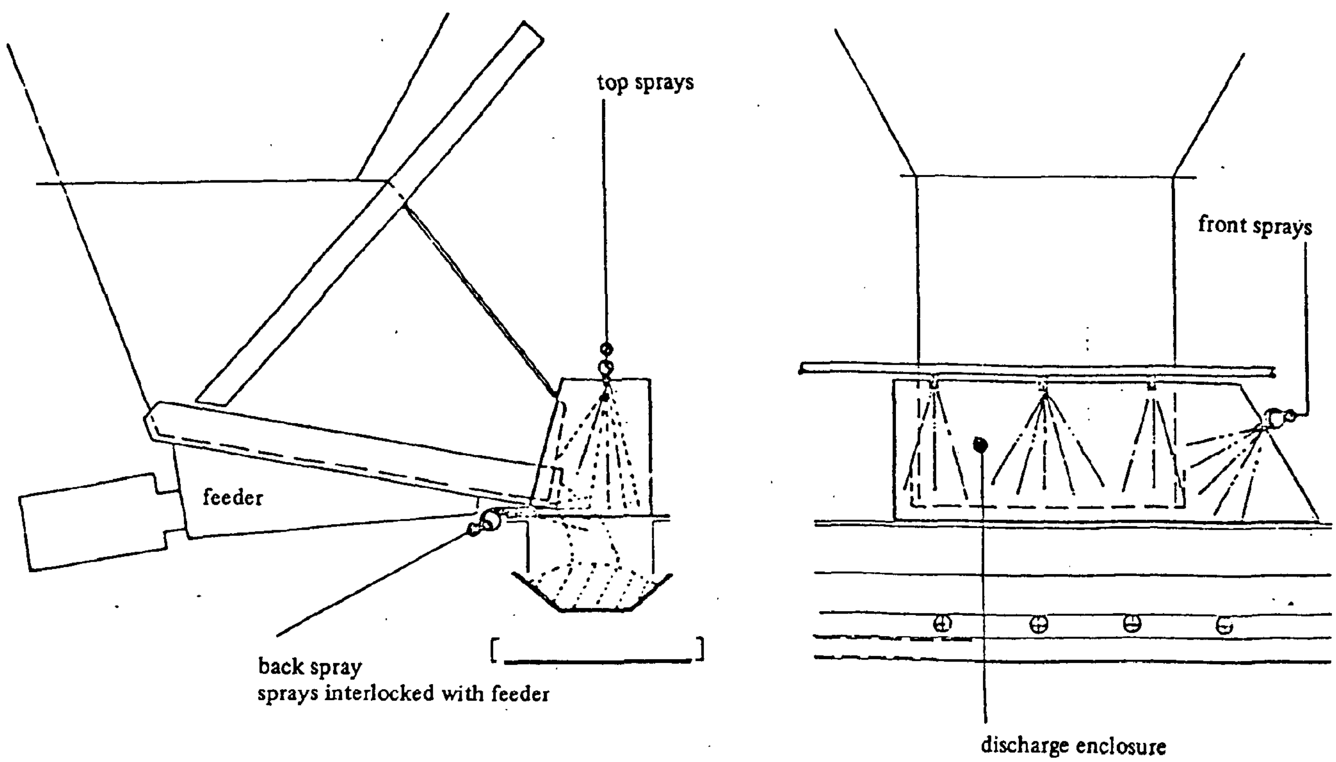


Figure 20: Typical application spray locations for chemical total treatment.

The important requirement is that a free-falling coal stream exists at the point of application of the sprays (Figure 20).

d. Treatment Characteristics

The treatment is designed to be dispersed throughout the coal to agglomerate fine particles into larger and hence denser particles. Water is used solely as a cheap vehicle for achieving dispersion of the chemical. The success of a treatment depends on its ability to maintain a binding action on fine particles as the moisture level of the coal falls.

Surface crust formation on stockpiles occurs within one hour and laboratory tests are available to evaluate the performance of the chemical for this form of static control (Figure 21). Since all coal in stockpiles is treated, disturbance of surfaces by wind erosion or during reclaiming operations exposes agglomerated coal which re-crusts within one hour. Chemicals are selected which are bio-degradable but which will maintain control for up to six weeks. Chemicals with possible side-effects in respect to contamination, safety and plant corrosion are not acceptable.

Stockpile Water Spraying Systems

Water spraying of stockpiled coal is a well established traditional approach to the control of dust emission from stockpile surfaces. Extensive evaluation including field testing indicates that the use of such systems may in fact increase dust emission. This appears to relate to the following:

a. short term supercharging resulting in water run-off and formation of channels in the stockpile surface. These channels

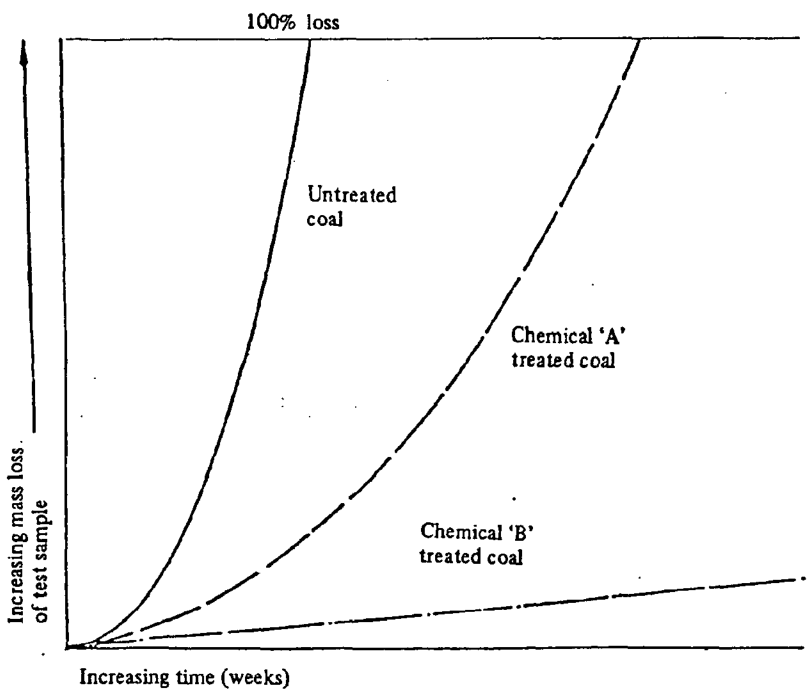


Figure 21: Typical static dust control characteristics of coal with chemical total treatment. (From United Nations, ESCAP Vol. 1, 1982)

increase air turbulence and stockpile surface area, which both increase dust emission on drying down.

b. coupled with supercharging is the effect of surface boiling which floats fines to the surface upon each water application.

The difficulty is to design a system which minimizes these effects and yet provides full, regular coverage of the complete exposed surfaces of stockpiles. Ideally, the use of fine mist sprays which depend on wind for dispersion gently onto stockpile surfaces is most likely to achieve this objective. However, the performance of such a system is unpredictable and depends very much on wind speed and direction. Use of large stream jet sprays is often necessary, particularly on high stockpiles to ensure complete surface wetting (Figure 22).

Although some authorities still consider such a system mandatory for open air coal stockpiles, success achieved to date with chemical total treatment systems indicates that use of water spraying may be confined to periods of very high wind. There is evidence that water is more readily re-absorbed on stockpile surfaces consisting of treated coal.

The salient features of this system are as follows:

a. Design Parameters

- Extensive field testing to establish:
  - maximum rates of water application which are possible without supercharging.
  - rates of moisture loss from top layer of stockpile surfaces due to moisture migration and re-evaporation.
  - the performance of various types of sprays at different discharge pressures and under varying wind speeds and directions.

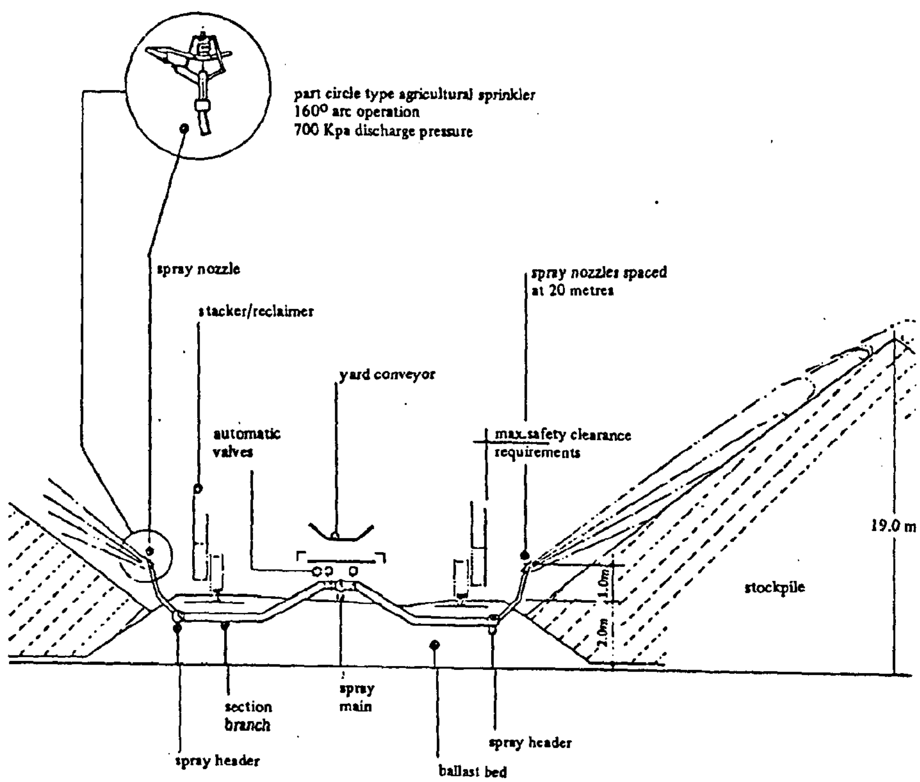


Figure 22: Typical arrangement of coal stockpile water sprays. (From United Nations, ESCAP Vol. 1, 1982)

All these tests have been conducted on actual full scale coal stockpiles and have achieved the greatest predictability of performance in the design with the least surface disturbance.

b. Spray Installations

Although mobile spray tankers can be used for small stockpiles, the fixed sprinkler system has been found more practical and reliable.

The use of a traversing spray bridge is usually impractical due to the regular use requirements conflicting with the operations of stacking and/or reclaiming equipment.

Sprinklers are usually piped in groups down both sides of stockpiles to facilitate progressive step spraying of the total stockpile surfaces. Simultaneous spraying of the total stockpile surfaces would dramatically increase the size of piping and pumps and the cost of the installation. In most cases limitations on water supply rates would also preclude such an approach.

c. Operation

It has been a general practice to incorporate three control modes as follows:

- fully automatic with spray cycle started and shut down in response to a controlling anemometer at a pre-set wind speed;
- semi-automatic with the ability to initiate the spray cycle manually at lower wind speed;
- manual override which allows manual selection of sprays in one sector of the total stockpile.

The anemometer also registers wind direction and provides automatic selection of either:

- windward side sprays and one pump; or
- both side sprays and two pumps for axial winds.

5. CONCLUSIONS

No one system of dust suppression is appropriate to all applications. Operations must be studied and understood in detail before a selection is made. Where "short term" rather than "long term" control is required, an entirely different method of suppression may be appropriate.

Obviously the incorporation of dust suppression systems into the design of a coal handling plant will add to both capital and operating costs. The obvious benefit is the improved air quality in the surrounding areas. However experience is revealing other possible economic benefits to plant owners and these may in the future be sufficient justification for the inclusion of dust suppression systems.

Favorable aspects of dust control on Guam include the following:

1. Coal is chemically treated for dust suppression at shipping port in Australia. This is the case in coal conveying and handling at the wharf as well as loading operations in colliers
2. Due to attrition some further treatment may be necessary at the receiving end and in the stock piling and handling of the coal
3. No long term stock piling. Turnover would be quite frequent

B. ENVIRONMENTAL ASPECTS OF COAL COMBUSTION

1. INTRODUCTION

The most obvious and major affect of burning coal is its contribution to air pollution and this always involves the public. It is the public, through local pressures or Government legislation, which decides the level of air pollution that is acceptable and pays either for the cost of control measures or for deteriorating quality of life if inadequate controls are applied.

The necessary or desirable control measures vary widely from country to country and from location to location. A location which has a strong prevailing wind blowing towards or over the ocean, like Guam, is far less likely to require stringent controls than an inland area surrounded by mountains which has little in the way of major wind patterns. In many cases the effects of air pollution are additive, hence the controls necessary in highly industrialized areas of central Europe or the United States need not be applicable in sparsely industrialized areas where a single source of combustion may be the only major emitter for a considerable distance, i.e. Cabras Island Power Plant.

When examining the environmental effects of coal combustion it is important to notice that, apart from hydroelectric power, the major sources of energy available are either nuclear power generation or the combustion process, either of coal, oil, gas or of minor local fuels such as wood.

Two opposing philosophies have developed with regard to the environmental effects of combustion. The first states, that should the material being emitted be objectionable then steps must be taken to remove the material before it is emitted. The second approach takes the view that the concentration of the pollutant at the point of emission is largely unimportant as long as the point of emission is sufficiently far from the recipient likely to be affected, that is, that the concentration by the time it reaches the recipient has been diluted to a point where it is no longer harmful. To achieve this dilution chimney stacks are high (250 m, 800 ft) with an exit gas velocity of about 23 m/sec. This second approach is very much less expensive than the first and, as a number of materials are also emitted by natural means, the logic of accepting an adequate dilution appears quite sound. For example the eruption of Mt. St. Helens, in May 1980 emitted approximately 400 million tons of dust. This is more than a 6000 MW power station would emit in 20,000 years.

The environmental affects of coal combustion can be conveniently discussed under three general headings, Gaseous Emissions, Particulate Emissions and Disposal of Residue or Ash.

2. GASEOUS EMISSIONS

The gaseous emissions which occur when coal is burned in a modern power station furnace are carbon dioxide, carbon monoxide, sulphur dioxide, sulphur trioxide, oxides of nitrogen and hydrocarbons.

Carbon Dioxide

Ten to twenty years ago there was a voluble school of thought which maintained that the constantly increasing concentration of carbon dioxide in the atmosphere would cause the temperature of the earth to increase with resultant melting of the solar ice caps and general disaster (the green house effect). This was based on various complex calculations and was claimed to be confirmed by the fact that a world-wide warming trend of about 0.6°C took place between 1880 and 1940. However, an equally voluble group of experts contended that the increased emission of particulates would have the reverse effect and indeed because of the high reflectivity of the particulate material, the earth far from going into a green house effect was in fact about to move into a new ice age. These scientists pointed to the fact that between 1940 and 1975 there had been a global cooling trend of 0.3°C. As very little is known about long term temperature changes on the planet, and as both groups have subsequently lapsed into silence, it is considered that this matter can be safely passed over for the forseeable future, or until some better or more soundly based evidence is available.

Carbon Monoxide

The levels of carbon monoxide emitted from modern power station operating with good combustion are very low and the quantities emitted are quite minor compared to the levels of automotive emissions which occur much closer to the receiving public.

Sulphur Dioxide

Experience with coals having sulphur contents on the order of 0.3 to 0.7 percent shows that about 5-10 percent of the sulphur remains fixed in the ash as sulphates and virtually all of the remainder goes up the chimney stack, as sulphur dioxide. This results in concentrations at the stack top on the order of 200 to 400 ppm of SO_2 (560 - 1120 mg/m^3). Given adequate stack height, the levels of sulphur dioxide in the air at ground level are well below the maximum ground level concentrations and annual mean concentration laid down by the World Health Organization as long term goals (200 g/m^3 for a 24 hour period and 60 g/m^3 annual average). A great deal of work has been done to quantify the levels of sulphur dioxide which are harmful but considerable conflict still exists between health experts on this matter. However, there is no body of opinion which considers that some of the early unfortunate episodes with high SO_2 levels and their adverse health effects were, in fact, the result not only of the high SO_2 but also of a synergistic effect between SO_2 and soot particles.

It has been estimated that man-made emissions of sulphur compounds are approximately two thirds of the total natural emissions.

While there is no doubt that excessive SO_2 concentrations are harmful both to man and to vegetation, various workers have pointed out that in certain sulphur deficient areas of the globe SO_2 emissions (at suitably low levels) can be beneficial to plant growth. A paper by Lambert and Turner of the N.S.W. Forestry Commission has reported on beneficial effects of the sulphur dioxide from a nearby Power Station on Adjacent State pine forests.

Sulphur Trioxide

Determinations of sulphur trioxide emissions from power stations in Australia indicates that the level is extremely low and certainly less than 10 ppm and probably less than 5 ppm. This level is diluted by some 10,000 times before reaching ground level and the concentration becomes so low as to be insignificant. The level of SO_3 emission is, apart from its obvious dependence on the sulphur content of the coal, also related to the combustion process and to the components in the ash with which it can react or be absorbed.

Hydrocarbon Emissions

Measurements of hydrocarbon levels in stack gases have shown the level to be considerably less than 1 ppm and it has been noted that the hydrocarbon content of the ambient air in the power station surrounding the duct may be higher than the hydrocarbon content of the flue gas. The quantity of hydrocarbons emitted daily from a major power station is so small compared to the normal emissions from motor vehicles that it is insignificant and need not be considered further.

Oxides of Nitrogen Emissions

The emission of oxides of nitrogen from a power station stack is almost entirely in the form of nitric oxide. This nitric oxide gradually oxidizes in the atmosphere to nitrogen dioxide over a period of some hours. Nitric oxide formation is a function of nitrogen content in the coal, furnace design, combustion method and flame temperature. For all practical purposes the nitrogen content in coal varies little and is not a major variable in nitric oxide emission levels. It has been found for N.S.W. coals in Australia that the level of formation of nitric oxide is only 50-60 percent of the levels quoted as being produced in similar plant in the United States (Ferrari et al., 1978).

With tangentially fired furnaces the Electricity Commission of N.S.W. normally experiences oxides of nitrogen levels of the order of 250 to 500 ppm and, as in the case of sulphur dioxide, with adequate stack design and stack height no problems are experienced with ground level concentrations of oxides of nitrogen. Indeed, ground level ambient measurements have shown that the oxides of nitrogen from sources such as motor vehicles is such that it completely masks the effect of power station emissions. The level of oxides of nitrogen produced in the furnace can be controlled to a considerable extent by careful regulation of the amount of excess air fed to the combustion process and also by the manner in which excess air is supplied. It has been found that by supplying less than the stoichiometric quantity of air initially, and increasing the secondary or tertiary air, the combustion process can be forced to take place over a longer period thus producing a lower temperature with resultant reduction of nitric oxide concentrations. However, if the combustion process must be considerably modified to control the formation of nitric oxide it could well result in an increase in hydrocarbon emission.

Carcinogens

Because of the very complete combustion which is necessary for efficient power station operation, the presence of hydrocarbons in the combustion products is extremely low and it is reasonable to expect that the percentage of hetrocyclic compounds in the hydrocarbons would also be very low. It has been reported that emissions of 3/4 benzpyrene (which is the usual carcinogen reported) is of the order of 0.03 to 0.6 ppm in the flue gas from pulverised coal fired boilers and the concentrations in normal urban air at .0015 to .003 ppm (R. Hangebrauck et al., 1964). From measurement of maximum ground level concentrations of sulphur dioxide it is known that flue gas is diluted some 10,000 times by the time it reaches ground level. Hence, using the quoted emission levels the maximum ground level concentrations of 3/4 benzpyrene would be 6 X 10^{-5} ppm or about 1/50 the concentration normally found in urban air.

3. PARTICULATE EMISSIONS

Although difficulties in control of particulate emissions (flyash), have been experienced in many plants in the past, emissions can in fact be controlled to any required limit. To achieve this control requires consideration to be given to the characteristics of the coal and of the characteristics of the coal ash. Also it is essential that dust collection plant of adequate size and characteristics be specified to achieve the high degree of particulate collection which is now required in most areas.

Early difficulties largely arose from an inadequate understanding of the factors involved in particulate emission control and, in particular, in attempts to use experience from one area in another where the coal being burnt was vastly different. Experience has shown that it is essential to take adequate samples of coals to be burnt in a new plant and subject these samples to stringent testing to determine the characteristics of the coal and its ash and its behavior in a precipitator or a fabric filter.

It is only in very recent times that a power station plant which is normally specified with spare condensate pump capacity, spare feed pump capacity and spare mill capacity is also being specified with spare dust collection capability.

The two major means of high efficiency dust collection are:

(a) Electrostatic Precipitators

(b) Fabric Filters.

Electrostatic Precipitators

Electrostatic precipitators are of two types. There are the so-called "hot-side" precipitators, which are located before the air heaters and operate at 300°C-400°C and "cold side" precipitators which are located after the air heaters and before the induced draft fans. Hot precipitators were introduced initially in the United States some 10-15 years ago when it was realized that some of the high resistivity dusts which were then being experienced had resistivity versus temperature curves such that the resistivity at the higher temperature was lower and therefore the sizing of the precipitator could be correspondingly reduced. However, a considerable part of this gain is lost because of the higher gas volume due to the higher temperature. Hot-side precipitators have also been prone to a number of problems and as a result, the number of installations now being made is low and they are rarely used outside the United States.

Cold-side precipitators have been in use for many years and a stage has been reached where, given adequate data on the characteristics of the coal to be burnt and its associated fly ash, the performance of a precipitator can be forecast with considerable accuracy. Hence, precipitators can now be designed and built to achieve any desired collection efficiency with a high degree of confidence. It should be noted that the size and therefore cost of precipitators can vary between wide limits and a size factor of two between the size of precipitators on boilers with similar outputs but burning different coals is by no means unusual. If must be emphasized that, to ensure that the performance is optimized it is essential that the characteristics of the coal and the ash be known and understood or that an extensive series of laboratory and pilot plant tests be carried out, preferably culminating in confirmatory full scale tests of some days duration in a plant with known precipitator capability.

A spare precipitator path should be installed if stack emission requirements are to be met without limitation on boiler output should internal on-line maintenance be required between annual outages. If there is doubt over the precipibility of the fly ash, insurance can be taken in the form either of the provision of space in the ductwork or by the inclusion of empty casings in each path. This will permit the addition of further capacity if necessary to improve precipitator performance at an increased cost.

Fabric Filters

Fabric filter installations have been in service on industrial plants such as smelters and incinerators for many years but they are relative late comers to the power industry. The initial installations were made in the early 1970's and most of those to date have been retrofits after problems with existing dust collection equipment. The longest service life so far experienced is of the order of 35-40,000 hours.

Fabric filters also come in two basic forms. These are the high gas to cloth ratio type (on the order of 6:1) where the cleaning is on-line and the low gas to cloth ratio type (with a gas to cloth ratio on the order of 2:1) where cleaning takes place when the cell is isolated from the gas path. In the first case the filter bags are supported on a wire frame or cage and the gas flow is from the outside of the bag to the inside. The bag is cleaned by injection of a short duration high energy "puff" of compressed air which causes the bag to flex away from the cage and the caked dust to fall from the outside of the bag. This happens with the plant in service and pulse rate is adjustable (normally every four or five minutes). The bag is normally made of felted material and the filtration takes place in, rather than on, the surface of the fabric.

In the second case, with the low gas to cloth ratio, filtration is from inside of the bag to the outside thus the dust collects on the inside of the bag. The filter consists of a number of separate cells each cell in the filter being taken out of service in turn by closing dampers and the bag agitated to cause the caked dust to fall into a hopper. The bags in this case are normally a woven material and the filtration takes place in the cake on the surface of the bag. The method of bag agitation varies depending on the material of the bag. In the case of fiberglass bags, cleaning is usually by means of reverse gas flow which causes the bags to partially collapse thus causing the cake to crack and fall from the bags. With organic fiber (homopolymer poly acrylonitrile - the other most commonly used material) the filter cake is dislodged by shaking the bags which are attached at the top (or closed end) to a frame which can be moved in a horizontal plane about 20 to 23 mm.

The choice of fabric or material to be used is dependent on a number of factors, the most important being the flue gas temperature expected at the filter. The U.S.A. usually uses fiberglass material coated with teflon or silicon graphite due to the higher backend temperatures associated with the higher sulphur coals which are being burnt and the need to keep temperatures high to avoid dew point conditions.

With attainable efficiencies of 99.5% plus for either electrostatic precipitators or fabric filters, the amount of particulate material which is discharged to the atmosphere is relatively low. However, considerable concern has been expressed that these particles are usually in the smaller size ranges and hence more potentially dangerous in that they can be more readily drawn into the lungs. Considerable effort is currently being exerted in an endeavor to quantify the composition and concentration of these finer particles. In 1978 Dr. D. Swain reported that, in general the levels of trace elements in ash are found to fall within fairly narrow ranges and that fly ashes, coal ashes, shale and soils have similar contents of trace elements. Hence the addition of fly ash in the earth's surface, especially highly diluted in rain, is unlikely to be harmful to plants and may be useful to marginal soils (Table 1).

4. DISPOSAL OF FURNACE AND FLY ASH

A usual method of disposal of ash is to transport it in the form of a slurry to an ash pond where it is allowed to settle and the water recycled. With the increasing trend to "zero discharge" of any polluted water from power station sites, the possibility of the discharge to the environment of undesirable levels of trace elements is low. Black coal ash is generally made up of alumina

Table 1

Trace Elements in Fly-Ashes from New South Wales, Queensland Bituminous Coals, and in Soils

Contents in eg/g dry fly-ash

Elements	*New South Wales*		*Queensland*	*Soils*
	Range	*Mean*		
Boron	20 – 400	150	25 – 150	2 – 100
Barium	250 – 300	250	250 – 400	100 – 3 000
Bismuth	up to 2	1	2 – 2	–
Chromium	40 – 60	50	80 – 200	5 – 1 000
Cobalt	10 – 30	15	10 – 20	1 – 40
Copper	40 – 150	80	250 – 300	2 – 100
Gallium	20 – 60	30	60 – 80	10 – 70
Germanium	3 – 60	15	20 – 25	up to 10
Lanthanum	150? – 200	150	150 – 200	30 – 300
Lead	20 – 150	40	100 – 300	2 – 200
Manganese	40 – 2 000	600	80 – 200	200 – 3 000
Molybdenum	0.3 – 6	4	4 – 7	0.2 – 5
Nickel	6 – 60	25	25 – 30	5 – 500
Scandium	20? – 40	25	40 – 60	10 – 25
Strontium	300 – 400	–	400 – 1 500	50 – 1 000
Thallium	up to 2	1	0.6 – 1	–
Tin	2 – 8	6	8 – 10	up to 10
Titanium	1 500 – 10 000	4 000	2 000 – 6 000	1 000 – 10 000
Vanadium	100 – 300	190	150 – 200	20 – 500
Yttrium	80 – 150	130	100 – 150	30 – 200
Zinc	20 – 600	130	800 – 2 500	10 – 300
Zirconium	150 – 400	250	200 – 250	60 – 2 000

(From United Nations, ESCAP Vol.1, 1982) silicates with small quantities of calcium, magnesium, sodium and potassium and very low concentrations of most trace elements. The water soluble component of these ashes is low, usually less than 0.1%, and most of the soluble material is in the form of calcium, magnesium and sodium salts.

One final point which should not be overlooked is that fly ash is a valuable pozzolite and can be used to replace up to 25% of the cement in concrete without adverse effects and with resultant economies.

C. POSITIVE IMPACTS

Not the least of environmental impacts associated with burning coal is how to manage the by product known as fly ash. For years, power plant operators and engineers had to treat fly ash as a waste product. The fly ash had market potential, but producers faced the challenge of finding buyers for it.

Fly ash is produced when coal is burned to produce steam for the boiler of an electric generating facility. Collection and disposal systems remove of fly ash each year from a facility's stack gas and usually move it to landfill locations.

Fly ash is composed chiefly of compounds of silicon, aluminum, iron and calcium, with smaller amounts of magnesium, titanium, sodium and potassium. Steaming coals (coal used for power generation) may contain as much as 15% ash.

About 20 years ago chemists and engineers had determined that fly ash is similar to the cement used to make concrete. Therefore, mixtures of fly ash and cement create material strengths comparable to mixtures using only cement, and products using fly ash are denser and less permeable.

Fly ash concrete mixtures are cheaper, generally selling for about one-third the cost of an equivalent amount of Portland cement. Initally on Guam the fly ash would likely be given away free as a waste, until a market for export was developed, if feasible. This is important to builders and road contractors because inflation has made most building materials more expensive. The construction industry could reduce material costs by replacing cement with fly ash. Reports state that nearly $70 can be saved whenever a ton of cement is replaced with fly ash.

Another use of fly ash reduces the need for asphalt. Highway departments can use a fly ash and lime mixture to stabilize roads. The mixture is worked into the top six inches of the roadbed, then water is added and the surface is rolled smooth. Workers add a thin sealing coat of asphalt and gravel to produce a smooth roadway with a hard base. The procedure replaces several inches of expensive asphalt with cheaper fly ash and lime, saving money and conserving oil.

The problem of land filling tons of fly ash annually poses serious problems. The potential for utilizing this waste as a commercial by-product can be developed. Obviously there would be local users on Guam, which has an extensive concrete construction industry.

The most positive environmental impact associated with this project is the decreased dependence on imported oil. Although Guam's dependence on oil would not be totally eliminated, it could be significantly reduced if coal were substituted as the primary fuel source, and it is cost effective.

Some oil will still be needed as a in reserve for the oil fired boilers in case of emergency. The oil fired boilers can then take over with no interruption in power. However, the reserve would only amount to approximately one month's supply of oil (120,000 BBLS).

Although this project proposes to add two 70 MW steam boiler units environmental impacts to the receiving water will remain unchanged. Cooling water will circulate at current rates with a Δ T° and no different than existing conditions.

VI. ALTERNATIVES TO THE PROPOSED PROJECT

There are at least three alternatives to the proposed action. These include no action, alternative site location and plan or design modification.

A. NO ACTION

The alternative of no action means that the Cabras Island Power Plant would continue to be fueled by oil and therefore continue to be dependent on the unstable world oil situation. Because this situation is so volatile and oil supply and prices can fluctuate it is appropriate to identify alternate fuel sources which can supply our island energy needs.

Coal as a fuel for power generation is not a new source. However, coal has been used as a fuel for the production of electricity only since the early 1900's and only dropped in demand when the supply and cost of oil gained favor in the early part of this century. With the recent (past 15 years) development of the OPEC Cartel the cost of oil reached unthought of highs which prompted those oil dependent and non-oil producing countries to look for more favorable sources of fuel.

Coal is a plentiful source of fuel and relatively cheap. It is found in vast quantities in America and in our near neighbor, Australia. Most environmental impacts associated with burning coal can now be controlled, and strict EPA can be attained for reasonable cost.

For these reasons the utiliztion of coal to fire Cabras Island Power Plant deserves attention as an alternative fuel source.

B. ALTERNATIVE SITE LOCATION

The possibility of building a coal fired facility at another site has been investigated. Other sites include the Piti and Tanguisson Power Plants already in operation. Both of these sites were not favorable for various reasons. The Piti Power Plant is the oldest Power generating facility on the island and is approaching maximum life expectancy. Economically it does not warrant the addition of a new steam boiler facility since it will probably be taken off line within a few years or kept for standby emergencies. The Tanguisson Power Plant, although relatively new (13 years old), could be retro-fitted for coal conversion and transport from the Cabras stockpile to Tanguisson. However, installation of coal burning boilers would not be cost effective, since Tauguisson is used only for peak shaving and to support scheduled and unscheduled outages.

For these reasons and since the Cabras Island Power Plant is relatively new (10 years old) with adequate land for stockpiling and unloading facilities and is located in a protected harbor, this facility has been chosen as the most favorable site.

C. ALTERNATIVE PLAN MODIFICATION

There are no firm plans, detailed drawings or blue prints available for this project. At this time the project is in the conceptual stage. General location of the wharf, stockpile, steam generating facility and other ancillary structures is only preliminary although there is probably little room for modifications. Portions of the shallow Tidal Flat A (Figure 8) to the west of the Cabras facility will require filling for coal stockpiling and a wharf could be constructed on the south face of the newly filled area for wharf facilities and of coal barges. The upper and lower Piti channel would be totally modified by widening and deepening to accommodate coal barges.

Within this general framework certain modifications can take place to enhance the project and protect the environment. However, detailed plans have not been developed and until they are, modifications are premature.

VII. GENERAL ADVERSE IMPACTS WHICH CANNOT BE AVOIDED

The major environmental impacts associated with this project which cannot be avoided involve dredging and filling operations to widen the Piti Channel and to create fast land for coal stockpiling. Actual dredge material to be taken from the Piti Channel and fill material requirements are unknown at this time since detailed plans are unavailable. However, approximately 8 acres will be required for the coal stockyard which will be filled land. The Piti Channel will require dredging for coal barge access which should generate more than enough material necessary for the stockyard. Dredging operations will remove existing bottom marine communities but provide deeper areas for new marine biological development. Filling operations will cover over a shallow water soft bottom community adjacent to the existing Cabras Day Tanks. A small islet situated in the middle of the lower Piti channel would be removed during channel reconstruction. This islet, like many in the Piti channel area, contributes to the variety of shorebirds feeding on sand flats.

Mitigation measures to lessen or prevent serious environmental impacts must be employed during construction as well as during actual operations. Since the major impacts will result from dredging and filling operations, mitigation measures will be necessary while these operations are ongoing. Such measures could include the following:

1. Use of properly placed and adequately sized silt screens to contain sediments so they settle out within the work area
2. Dredging and filling operations could be restricted to flood tides or periods of slack water

3. Only essential areas should be dredged or filled
4. Proper stabilization techniques should be employed such as compaction, use of a 1:2 or 1:3 slope, riproping the slopes and stabilization by planting vegetation
5. If possible, spoil material should be transported for as short a distance as possible. Excess spoil should be stored on shore or utilized in an ongoing project
6. Coordination with projects in the vicinity should be attempted to lessen the duration of or overall impacts to the environment. An example of this would be the planned Harbor of Refuge project being coordinated by the Port Authority

Mitigation measures and an environmentally sound operations plan will have to be devised for actual coal handling and storage activities. Some important measures that should be considered for an environmental protection plan would include the following:

1. Care in handling, unloading and loading should be stressed and all personnel should be properly trained
2. Use of sprayers when off-loading coal from the barges to the yard and to the stockpiles is necessary to control coal dust and maintain high air quality standards
3. Unloading and stockpiling operations should be curtailed or modified during periods of high winds and when winds are blowing in unfavorable directions

4. Coal stockpiles should be properly covered when not being used to prevent dust and/or runoff problems
5. The sprayer liquid should be properly collected in a retaining basin before separation to ensure that the slurry does not contaminate the marine environment

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APPENDICES

APPENDIX

A. Checklist of marine benthic algae and seagrasses observed in the Commercial Port/Piti Channel area, Apra Harbor, December 1976 and January 1977.

B. A checklist of the macroinvertebrates found in the Piti-Cabras outfall study area between April 1972 and March 1977.

C List of corals observed within study areas.

D. A checklist of fishes which compares the ichthyofauna of the Piti and Cabras outfall lagoon in 1972 and 1977.

E. Fishes observed at survey sites in Apra Harbor on December 6, 1976.

F. Zooplankton abundance at several sampling sites throughout the study area.

G. List of birds in Piti Channel Area.

H. List of miscellaneous animals in Piti Channel Area.

Appendix A. Checklist of marine benthic algae and sea-grasses observed in the Commercial Port/Piti Channel area, Apra Harbor, December 1976 and January 1977.

Species	Outfall Lagoon	Piti Channel	Tidal Flat	Patch Reef	Jade Shoal
Cyanophyta					
Calothrix pilosa Harvey					X
Hormothamnion enteromorphoides B. and Fl.	X				X
Microcoleus lyngbyaceus (Kütz.) Crouan	X	X	X	X	X
Schizothrix calcicola (Ag.) Gomont					X
Schizothrix mexicana Gomont	X				X
Chlorophyta					
Avrainvillea obscura J. Ag.	X	X	X		
Caulerpa racemosa (Forssk.) J. Ag.				X	
Caulerpa serrulata (Forssk.) J. Ag.				X	
Enteromorpha clathrata (Roth) J. Ag.			X		
Halimeda macroloba Decaisne			X	X	
Halimeda opuntia (L.) Lamx.	X	X	X	X	
Tydemannia expeditionis W. v. Bosse					X
Phaeophyta					
Dictyota bartayresii Lamx.	X			X	X
Feldmannia indica (Sonder) Womersley and Bailey					X
Hydroclathrus clathratus (C. Ag.) Howe					X
Lobophora variegata (Lamx.) Womersley					X
Padina tenuis Bory	X	X	X	X	X
Sargassum polycystum C. Ag.	X				
Sphacelaria tribuloides Meneghini				X	X
Turbinaria ornata (Turner) J. Ag.					X

Species	Outfall Lagoon	Piti Channel	Tidal Flat	Patch Reef	Jade Shoal
Rhodophyta					
Amphiroa foliacea Lamx.					X
Asparagopsis taxiformis (Delile) Collins and Harvey [sporophyte stage]					X
Centroceras clavulatum (C. Ag) Montagne					X
Galaxaura filamentosa Chou					X
Galaxaura oblongata (E. and S.) Lamx.					X
Gelidiella cf. *myriocladia* (Boerg.) Feldm. and Hamel	X				
Gelidiopsis intricata (Ag.) Vickers				X	
Gracilaria salicornia (Mert.) Grev.	X			X	
Hypnea esperi Bory				X	
Jania capillacea Harvey				X	X
Laurencia sp.					X
Leveillea jungermannioides Harvey				X	
Polysiphonia sp.	X		X	X	X
Spyridia filamentosa (Wulf.) Harvey	X				
Anthophyta					
Enhalus acoroides (L. f.) Royle			X		
Halophila minor (Zool.) Hartog	X		X		
NUMBER OF SPECIES	13	4	9	13	21

Source: University of Guam Marine Laboratory, *Marine Environmental Baseline Report, Commercial Port, Apra Harbor, Guam*. For U.S. Army Corps of Engineers, 1977. Table 9.

Appendix B

A checklist of the macroinvertebrates found in the Piti-Cabras outfall study area between Arpil 1972 and March 1977.

AREA I - Outfall Lagoon
AREA II - Upper and Lower Piti Channel
AREA III - Tidal Flats B, C, and D
AREA IV - Patch Reef

	AREA			
	I	II	III	IV
Phylum Porifera				
Cinachyra australiensis (Carter)				X
Spirastrella vagabunda (Ridley)	X	X	X	X
Terpios Sp				X
Phylum Cnidaria				
Class Scyphozoa				
Cassiopea andromeda (Forskal)	X		X	
Class Anthozoa				
Family Pocilloporidae				
Pocillopora damicornis (L.)				
Family Agariciidae				
Pavona decussata Dana				X
Pavona frondifera (Lamarck)				X
Pavona (Polyastra) obstusata (Quelch)				X
Family Poritidae				
Porites andrewsi Vaughan				X
Porites cocosensis Wells				X
Porites lutea Milne Edwards & Haime	X	X	X	X
Porites (Synaraea) convexa Verrill				X
Family Faviidae				
Leptastrea purpurea (Dana)				X
Family Oculinidae				
Galaxea clavus (Dana)				X
Phylum Annelida				
Eurythoe sp.		X		
Sabellastarte indica (Savigny)	X			
Phylum Mollusca				
Class Gastropoda				
Family Cerithidae				
Cerithium morus Bruguiere			X	
Cerithium nodulosum Bruguiere	X	X		
Cerithium ravidum Philippi	X	X		
Family Conidae				
Conus rattus Bruguiere	X			

	AREA I	II	III	IV
Family Cymatiidae				
Cymatum nicobaricum (Roding)	X	X		
Cymatum pileare (L.)	X			
Family Cypraeidae				
Cypraea annulus L.	X			
Cypraea erosa L.	X			
Cypraea margarita Dillwyn	X			
Cypraea moneta L.	X	X		
Cypraea tigris L.	X	X	X	
Family Littorinidae				
Littorina scabra (L.)	X		X	
Family Muricidae				
Drupa fragum Roding		X		
Drupa ricina L.	X			
Morula triangulatum (Pease)		X		
Morula uva (Roding)		X	X	
Family Naticidae				
Natica qualtieriana Recluz	X			
Polinices pyriformis Recluz	X	X		X
Family Neritidae				
Nerita albicilla L.	X	X		
Nerita plicata L.	X			
Nerita polita L.		X		
Family Patellidae				
Patella sp.	X			
Family Phenacolepatidae				
Phenacolepas crenulata (Broderip)	X	X	X	
Phenacolepas sp.		X		
Family Planaxidae				
Planaxis sulcatus (Born)	X	X	X	
Family Strombidae				
Lambis lambis (L.)	X	X		X
Strombus luhuanus L.	X	X		X
Strombus mutabilis Swainson	X	X		
Family Trochidae				
Trochus niloticus L.	X	X		
Family Vasidae				
Vasum turbinellus L.	X	X		

	AREA I	II	III	IV
Class Amphineura				
Acanthochitin sp.	X	X		
Class Bivalvia				
Charma sp.		X	X	
Crassostrea culculletta		X	X	X
Gafrarium tumidum L.		X	X	X
Isognomon sp.		X	X	X
Malleus malleus (L.)		X	X	X
Pinna sp.	X	X		X
Septifer bilocularis L.		X	X	
Phylum Arthropoda				
Class Crustacea				
Calappa hepatica L.	X	X		
Calcinus elegans (H. Milne Edwards)	X			
Calcinus laevimanus (Randall)	X			
Calcinus latens (Randall)	X	X	X	
Cardiosoma sp.	X	X	X	X
Carpilius maculatus (L.).			X	
Clibanarius humilis (Dana)	X	X	X	
Clibanarius stratiolatus (Dana)	X	X	X	
Dardanus megistos (Herbst)	X		X	
Dardanus scutellatus (Dana)			X	
Macropthalmus sp.	X			
Uca chlorophthalmus crassipes (Adams & White)	X	X		
Uca vocans (L.)			X	
Additional hermit crabs	X		X	
Portunid crabs	X		X	
Supra-littoral grapsid crabs	X	X	X	
Xanthid crabs		X		
Phylum Echinodermata				
Actinopyga echinites (Jaeger)	X			
Bohadschia argus (Jaeger)	X	X		X
Bohadschia bivittata (Mitsukuri)	X	X		
Bohadschia marmorata (Jaeger)	X		X	
Diadema setosum (Leske)	X	X		X
Echinometra mathaei (de Blainville)	X			
Euapta sp.	X			
Holothuria atra Jaeger	X			X
Holothuria cinerascens (Brandt)	X			
Holothuria impatiens (Forskal)	X			
Holothuria leucospilota Brandt	X			
Opheodesoma grisea (Semper)	X	X		

Source: University of Guam Marine Laboratory, *Power Plants and the Marine Environment in Piti Bay and Piti Channel, Guam 1976-1977 Observation and General Summary*. For the Guam Power Authority.

Appendix C. List of corals observed within study areas.

CORALS	SASA BAY (No Corals at Sta. A-E, G and M-Q)									JADE SHOALS		PITI CHANNEL (No Corals at Sta. 1-5,8 and 14)							
	F	H	I	J	K	L	R	S	T	Upper Platforms	Slopes	6	7	9	10	11	12	13	15
CLASS-ANTHOZOA																			
ORDER-SCLERACTINIA																			
SUBORDER-ASTROCOENIINA																			
FAMILY-ASTROCOENIIDAE																			
Stylocoeniella armata (Ehrenberg)					+			+	+	+	+								
Stylocoeniella guentheri (Bassett-Smith)			+	+	+						+								
FAMILY-THAMNASTERIIDAE																			
Psammocora contigua (Esper)					+				+	+	+								
Psammocora nierstrazi Van der Horst											+								
Psammocora samoensis Hoffmeister											+								
Psammocora (Plesioseris) haimeana Milne Edwards Haime									+		+								
Psammocora (Stephanaria) togianensis Umbgrove				+					+		+								
FAMILY-POCILLOPORIDAE																			
Stylophora mordax (Dana)										+									
Seriatopora hystrix Dana					+				+		+								
Pocillopora damicornis (Linnaeus)	+	+	+	+	+	+	+	+	+	+	+					+	+		+
Pocillopora danae Verrill					+				+	+									
Pocillopora elegans Dana											+								
Pocillopora eydouxi Milne Edwards Haime											+								
Pocillopora meandrina Dana					+				+		+								
Pocillopora verrucosa (Ellis and Solander)					+						+								
FAMILY-ACROPORIDAE																			
Acropora aspera (Dana)				+															
Acropora brueggemanni (Brook)					+						+								
Acropora delicatula (Brook)					+					+									
Acropora formosa (Dana)				+	+				+		+								

Appendix C.(continued)

CORALS	SASA BAY (No Corals at Sta. A-E, G, and M-Q)									JADE SHOALS		PITI CHANNEL (No Corals at Sta. 1-5, 8, and 14)							
	F	H	I	J	K	L	R	S	T	Upper Platform	Slopes	6	7	9	10	11	12	13	15
Acropora humilis (Dana)					+				+	+									
Acropora kenti (Brook)					+														
Acropora nasuta (Dana)											+								
Acropora palifera (Lamarck)					+				+	+	+								
Acropora rambleri (Bassett-Smith)					+														
Acropora rayneri (Brook)					+						+								
Acropora surculosa (Dana)					+				+	+	+								
Acropora teres (Verrill)											+								
Acropora virgata (Dana)					+				+		+								
Astreopora myriophthalma (Lamarck)										+									
Montipora ehrenbergi Verrill	+	+	+	+	+	+	+	+	+										
Montipora foveolata (Dana)					+				+		+								
Montipora granulosa Bernard				+															
Montipora hoffmeisteri Wells					+				+	+	+								
Montipora lobulata Bernard				+	+	+		+	+	+	+								
Montipora monasteriata (Forskaal)											+								
Montipora patula Verrill			+		+				+										
Montipora tuberculosa (Lamarck)									+		+								
Montipora verrilli Vaughan				+	+		+	+	+	+	+								
Montipora verrucosa (Lamarck)					+				+		+								
Montipora spumosa ?			+	+	+			+	+										
Montipora sp. 1 (Papillate)			+							+									
Montipora sp. 2 (Glabrous)				+						+									
SUBORDER-FUNGIINA																			
FAMILY-AGARICIIDAE																			
Pavona decussata Dana					+					+	+								+
Pavona frondifera (Lamarck)																			+
Pavona minuta Wells					+						+								
Pavona praetorta (Dana)					+						+								
Pavona varians Verrill					+				+		+								

Appendix C. (continued)

CORALS	SASA BAY (No Corals at Sta. A-E, G, and M-Q) F	H	I	J	K	L	R	S	T	JADE SHOALS Upper Platforms	JADE SHOALS Slopes	PITI CHANNEL (No Corals at Sta. 1-5,8 and 14) 6	7	9	10	11	12	13	15
Pavona (Polyastra) obtusata (Quelch)				+	+			+	+	+	+								
Pavona (Polyastra) venosa Ehrenberg					+				+	+									
Pavona (Polyastra) sp. 1					+					+	+								
Leptoseris incrustans (Quelch)					+				+		+								
Leptoseris mycetoseroides Wells					+						+								
Pachyseris speciosa (Dana)											+								
FAMILY-FUNGIIDAE																			
Cycloseris sp. 1											+								
Fungia (Fungia) fungites (Linnaeus)					+					+	+								
Fungia (Pleractis) scutaria Lamarck										+									
Herpolitha limax (Esper)											+								
FAMILY-PORITIDAE																			
Goniopora lobata Milne Edwards and Haime									+		+								
Goniopora tenuidens (Quelch)									+		+								
Stylaraea punctata Klunzinger			+	+				+		+									
Porites andrewsi Vaughan	+	+	+	+	+	+	+	+	+	+	+								+
Porites australiensis Vaughan				+	+			+	+	+	+								+
Porites cocosensis Wells				+	+			+	+	+	+								+
Porites lichen Dana				+						+	+								
Porites Lobata Dana				+					+	+	+								
Porites lutea Milne Edwards and Haime	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Porites murrayensis Vaughan				+	+			+			+								
Porites fragosa Dana					+														
Porites sp. 1 (massive)									+										
Porites (Synaraea) convexa Verrill		+		+	+			+	+	+	+								+
Porites (Synaraea) hawaiiensis Vaughan					+				+		+								
Porites (Synaraea) horizontalata Hoffmeister			+	+	+			+	+		+								
Porites (Synaraea) iwayamaensis Eguchi			+	+	+	+		+	+	+	+								+
Alveopora allingi Hoffmeister											+								

Appendix C. (continued)

CORALS	SASA BAY (No Corals at Sta. A-E, G, and M-Q)									JADE SHOALS		PITI CHANNEL (No Corals at Sta. 1-5,8 and 14)							
	F	H	I	J	K	L	R	S	T	Upper Platform	Slopes	6	7	9	10	11	12	13	15
SUBORDER-FAVIINA																			
FAMILY-FAVIIDAE																			
Favia favus (Forskaal)					+														
Favia pallida (Dana)					+				+	+									
Favia speciosa (Dana)											+								
Favia stelligera (Dana)									+										
Favites flexuosa (Dana)					+														
Goniastrea australiensis (Milne Edwards and Haime)											+								
Goniastrea parvistella (Dana)									+		+								
Goniastrea pectinata (Ehrenberg)					+				+		+								
Goniastrea retiformis (Lamarck)										+									
Platygyra daedalea (Ellis and Solander)				+	+					+	+								
Platygyra rustica (Dana)					+					+	+								
Leptoria phrygia (Ellis and Solander)									+		+								
Hydnophora microconos (Lamarck)					+						+								
Diploastrea heliopora (Lamarck)					+						+								
Leptastrea bottae (Milne Edwards and Haime)					+				+	+									
Leptastrea purpurea (Dana)	+	+	+	+	+	+	+	+	+	+	+								+
Cyphastrea microphthalma (Lamarck)								+			+								
Cyphastrea chalcidicum (Forskaal)									+		+								
Echinopora lamellosa (Esper)					+				+		+								
Plesiastrea versipora (Lamarck)					+						+								
FAMILY-OCULINIDAE																			
Galaxea clavus (Dana)			+	+	+			+	+	+	+								+
Galaxea fascicularis (Linnaeus)					+					+	+								
Acrhelia horrescens (Dana)					+				+		+								
FAMILY-MUSSIDAE																			
Lobophyllia corymbosa (Forskaal)				+	+				+	+									
Lobophyllia costata (Dana)				+	+						+								

Appendix C.(continued)

CORALS	SASA BAY (No Corals at Sta. A-E, G, and M-Q) F	H	I	J	K	L	R	S	T	JADE SHOALS Upper Platform	Slopes	PITI CHANNEL (No Corals at Sta. 1-5,8 and 14) 6	7	9	10	11	12	13	15
Lobophyllia hemprichii (Ehrenberg)				+	+														
Acanthastrea echinata (Dana)									+		+								
FAMILY-PECTINATA																			
Echinophyllia aspera (Ellis and Solander)											+								
Mycedium sp. 1											+								
Pectinia lactuca (Pallas)											+								
SUBORDER-CARYOPHYLLIINA																			
FAMILY-CARYOPHYLLIIDAE																			
Euphyllia glabrescens Chamisso and Eysenhardt				+	+						+								
SUBORDER-DENDROPHYLLIINA																			
FAMILY-DENDROPHYLLIIDAE																			
Tubastraea aurea (Quoy and Gaimard)										+									
ORDER-COENOTHECALIA																			
Heliopora coerulea (Pallas)				+	+			+	+		+								
CLASS-HYDROZOA																			
ORDER-MILLEPORINA																			
FAMILY-MILLEPORIDAE																			
Millepora exaesa Forskaal					+				+	+	+								
Millepora dichotoma Forskaal				+					+	+	+								
Millepora platyphylla Hemprich and Ehrenberg					+				+	+	+								
TOTAL SPECIES	5	6	13	32	68	7	6	20	55	42	81	1	1	1	1	2	2	1	11
TOTAL GENERA	4	4	7	15	25	4	4	10	24	19	35	1	1	1	1	2	2	1	5

	Entire Study Area	Sasa Bay	Jade Shoals	Piti Channel
TOTAL SPECIES	110	88	94	11
TOTAL GENERA	40	31	39	5

Source: University of Guam Marine Laboratory, Marine Environmental Baseline Report, Commercial Port, Apra Harbor, Guam. For U.S. Army Corps of Engineers, 1977, Table 10.

Appendix D. A checklist of fishes which compares the ichthyofauna of the Piti and Cabras outfall lagoon in 1972 and 1977. TNTC = Too numerous to count, D = Dominant (10+), C = Common (6-10), P = Present (2-5), R = Rare (1).

Fish Species	1972	1977
ACANTHURIDAE		
Acanthurus lineatus (L.)	R	-
A. triostegus (L.)	D	-
A. xanthopterus Cuvier & Valencinnes	D	D
Ctenochaetus striatus (Quoy & Gaimard)	P	-
Naso unicornis (Forskal)	P	-
Zebrasoma veliferum (Bloch)	P	R
APOGONIDAE		
Apogon leptocanthus Bleeker	P	TNTC
Paramia quinquilineata (Cuvier & Valencinnes)	-	D
Sphaerania orbiculatus (Cuvier)	-	P
AULOSTOMIDAE		
Aulostomus chinensis (L.)	-	P
BALISTIDAE		
Rhinecanthus aculeatus (L.)	P	R
R. rectangulus (Bloch & Schneider)	R	-
R. verrucosus (L.)	-	R
BLENNIIDAE		
Petroscrites mitratus (Ruppell)	P	D
CANTHIGASTERIDAE		
Canthigaster solandri (Richardson)	P	C
CARANGIDAE		
Caranx melampygus Cuvier & Valenciennes	D	-
CHAETODONTIDAE		
Chaetodon auriga Forskal	P	-
C. ephippium Cuvier	C	P
C. lunula (Lacepede)	-	P
C. trifasciatus Mungo Park	P	-
C. ulietensis Cuvier	P	-
ELEOTRIDAE		
Asterropteryx sp.	P	-

Appendix D. (continued)

Fish Species	1972	1977
GOBIIDAE		
Amblygobius albimaculatus (Ruppell)	P	P
Gnatholepsis deltoides (Seale)	P	-
Oplopomus oplopomus (Cuvier & Valenciennes)	D	C
Obtortiophagus koumansi (Whitely)	TNTC	TNTC
Penophthalmus keolreuteri (Pallas)	-	C
HOLOCENTRIDAE		
Flammeo summara (Forskal)	-	C
LABRIDAE		
Epibulus insidiator (Pallas)	-	R
Halichoeres centiquadrus (Lacepede)	-	C
H. trimaculatus (Quoy & Gaimard)	C	D
Hemigymnus melapterus (Bloch)	-	R
LEIOGNATHIDAE		
Gerres argyreus (Bloch & Schneider)	P	D
Leiognathus equulua (Forskal)	P	P
LUTJANIDAE		
Lethrinus rhodopterus Bleeker	C	-
Lutjanus monostigmus (Cuvier & Valenciennes)	P	D
L. vaigiensis (Quoy & Gaimard)	C	D
Plectorhynchus pintus (Thunberg)	R	-
Scolopsis cancellatus (Cuvier & Valenciennes)	P	D
MURAENIDAE		
Gymnothorax sp.	-	P
MUGILOIDIDAE		
Parapercis cephalopunctata (Seale)	-	R
MULLIDAE		
Mulloidichthys auriflamma (Forskal)	-	P
M. samoensis (Gunther)	P	P
POMACENTRIDAE		
Abudefduf saxitalis (L.)	-	D
A. coelestinus (Cuvier)	P	C
Dascyllus aruanus (L.)	P	TNTC
Eupomacentrus lividus (Bloch & Schneider)	P	D

Appendix D. (continued)

Fish Species	1972	1977
SCARIDAE		
Scarus sordidus Forskal (juveniles)	TNTC	TNTC
Scarus sp.	R	D
SIGANIDAE		
Siganus spinus (L.)	TNTC	C
SPHYRAENIDAE		
Sphyraena sp.	R	R
Sub Totals	37	38
Total	51	

Source: University of Guam Marine Laboratory, Power Plants and the Marine Environment of Piti Bay and Piti Channel, Guam: 1975-1976 Observations. For the Guam Power Authority.

Appendix E. Fishes observed at survey sites in Apra Harbor on December 6, 1976. Present (+). Abundant (++).

Species	Jade Shoals 1 Meter	Jade Shoals 10 Meters	Mouth of Piti Channel
ACANTHURIDAE			
Acanthurus mata Cuvier and Valenciennes			1
A. nigroris Cuvier and Valenciennes	1		
A. xanthopterus Cuvier and Valenciennes	+		
Ctenochaetus striatus (Quoy & Gaimard)	1	3	2
Zebrasoma flavescens (Bennett)	+	1	
Z. veliferum (Bloch)		3	
APOGONIDAE			
Apogon compressus (Smith & Radchffe)			100
Apogon juveniles			765
Paramia quinquelineata (Cuvier and Valenciennes)	1		
BALISTIDAE			
Sufflamen chrysoptera (Bloch & Schneider)	+	1	
BLENNIIDAE			
Meiacanthus atrodorsalis (Gunther)	4		
CHAETODONTIDAE			
Chaetodon auriga Forskal	1		
C. bennetti Cuvier	1		
C. citrinellus Cuvier	+		
C. ephippium Cuvier	+		3
C. trifasciatus Mungo Park	5	1	21
C. ulietensis Cuvier	1	1	2
Heniochus chrysostomus Cuvier	+		
GOBIIDAE			
Amblygobius albimaculatus (Ruppell)	+	1	3
HEMIRAMPHIDAE			
unidentified half-beaks		+	
HOLOCENTRIDAE			
Adioryx spinifer (Forskal)		1	
Flammeo sp.	+		

Appendix E. (Continued)

Species	Jade Shoals 1 Meter	Jade Shoals 10 Meters	Mouth of Piti Channel
LABRIDAE			
Epibulus insidiator (Pallas)	+	1	
Gomphosus varius Lacepede	1		
Halichoeres trimaculatus (Quoy & Gaimard)	1		
Hemigymnus melapterus (Bloch)			1
Labroides dimidiatus (Cuvier and Valenciennes)	+	1	
Stethojulis bandanensis Bleeker	1		
LUTJANIDAE			
Aphareus furcatus (Lacepede)	+		
Caesio caerulaureus Lacepede	++		
Lutjanus vaigiensis (Quoy & Gaimard)	+	1	1
Scolopsis cancellatus (Cuvier and Valenciennes)			+
POMACENTRIDAE			
Abudefduf coelestinus (Cuvier)	1		
Amblyglyphidodon curacao (Bloch)	34	65	
Amphiprion melanopus Bleeker	+		
A. perideraion Bleeker		+	
Chromis caerulea (Cuvier)	1	46	233
Dascyllus aruanus (Linnaeus)	+	35	70
D. trimaculatus (Ruppell)	+	3	
Eupomacentrus albifasciatus (Schlegel and Muller)	1		
E. lividus (Bloch and Schneider)			36
E. nigricans (Lacepede)	6		
Glyphidodontops leucopomus (Lesson)	+		
Plectroglyphidodon leucozona (Bleeker)			7
unidentified sp. A	5		
unidentified sp. B		7	
SCARIDAE			
Scarus sordidus Forskal	+		5

Appendix E. (continued)

Species	Jade Shoals 1 Meter	Jade Shoals 10 Meters	Mouth of Piti Channel
ZANCLIDAE			
Zanclus cornutus (Linnaeus)	+	1	
Transect length (m)	40	75	190
Number of species censused	17	17	15
Total species observed	36	19	15
Number of individuals/m^2	.94	1.14	3.29

Source: University of Guam Marine Laboratory, *Marine Environmental Baseline Report, Commercial Port, Apra Harbor, Guam.* For U.S. Army Corps of Engineers, 1977, Table 13.

Appendix F. Zooplankton abundance at several sampling sites throughout the study area. Abundances in number per m of water filtered. P.C. = Piti Canal, O.L. = Outfall Lagoon, P.Ch. = Piti Channel, 2°Ch. = Secondary Channel, C.P. = Commercial Port, A.H. = Outer Apra Harbor, RCB = Reserve Craft Bay. See Fig. 35 for sampling locations.

	September 1976						
Organisms	P.C.	O.L.	P.Ch.	2°Ch.	C.P.	A.H.	RCB
foraminiferans	0.70	3.1	-0-	-0-	-	-0-	3.1
medusae	-0-	0.39	-0-	0.12	-	-0-	-0-
pteropods	-0-	-0-	-0-	-0-	-	-0-	0.30
gastropods	0.38	-0-	0.82	-0-	-	-0-	-0-
polychaete larvae	-0-	0.78	-0-	-0-	-	-0-	-0-
ostracods	-0-	-0-	-0-	-0-	-	-0-	-0-
copepods	0.06	78.	22.	13.	-	43.	892.
mysids	-0-	-0-	-0-	-0-	-	-0-	-0-
Lucifer	-0-	-0-	0.41	-0-	-	-0-	-0-
stomatopod larvae	-0-	-0-	-0-	-0-	-	-0-	0.38
crab zoea larvae	0.17	2.7	49.	83.	-	1.5	17.
shrimp zoea larvae	0.09	3.5	11.	4.0	-	3.0	14.
chaetognaths	-0-	-0-	-0-	-0-	-	0.65	9.0
larvaceans	-0-	-0-	-0-	-0-	-	-0-	3.7
fish eggs	0.96	58.	11.	-0-	-	6.9	3.6
fish larvae	0.03	5.4	7.8	1.3	-	1.7	7.8
miscellaneous	0.06	1.2	1.2	-0-	-	-0-	-0-
Total Individuals	2.4	150.	546.	102.	-	57.	951.
Total Volume (ml)	1.4	2.85	2.7	4.0	-	4.25	23.4
Vol./m^3(ml)	0.041	0.032	0.030	0.055	-	0.095	0.28

Appendix G

LIST OF BIRDS IN PITI CHANNEL AREA

Common Name	Scientific Name	Remarks* 1	2	3	4	5	6
Yellow Bittern	*Ixobrychus sinensis*	T		X	X	X	
Cattle Egret	*Bubulcus ibis*						X
Pacific Reef Egret	*Egretta sacra*	E				X	
Guam Rail	*Rallus owstoni*	T		X	X		
Lesser Golden Plover	*Pluvialis dominica*						X
Whimbrel	*Numenius phaeopus*		X		X	X	
Bristle-thighed Curlew	*N. tahitiensis*						X
Long-billed Curlew	*N. madagascariensis*						X
Common Sandpiper	*Actitis hypoleucos*		X		X		X
Grey-tailed Tattler	*Heteroscelus brevipes*				X		
Wandering Tattler	*H. incanus*				X		X
Ruddy Turnstone	*Arenaria interpres*		X		X		X
Sanderling	*Calidris alba*				X		
Sharp-tailed Sandpiper	*C. acuminata*						X
Mongolian Dotterel	*Charadrius mongolus*				X		
Brown Noddy	*Anous stolidus*	T			X		
White Tern	*Gygis alba*	E		X	X	X	
Philippine Turtle Dove	*Streptopelia bitorquata*				X		X
Marianas Fruit Dove	*Ptilinopus roseicapilla*	E					X
Micronesian Kingfisher	*Halcyon cinnamomina*	E		X	X		X
Chestnut Mannikin	*Lonchura malacca*					X	
Eurasian Tree Sparrow	*Passer Montanus*				X		
Black Drongo	*Dicrurus macrocercus*					X	

* 1/ On proposed List of Endangered and Threatened Species, prepared by Endangered and Threatened Species Committee of Guam.

2/ Observed feeding in Piti Channel area, January 1979.

3/ Observed flying over Piti Channel area, January 1979.

4/ Reported in general area of Piti Channel according to Mr. Mark Jenkins, Division of Natural Resources, Government of Guam, January 1979.

5/ Observed in Piti Channel area, March 1977.

6/ Reported in general Apra Harbor region by sources in Guam Fish and Wildlife Division, Division of Natural Resources, March 1977.

Sources: Guam Coastal Management Program Technical Reports Vol. 1, *An Ecological Survey of Pristine Terrestrial Communities on Guam.*

Carl Couret, U.S. Fish and Wildlife Service (Personal Communication).

Jerry Ludwig, U.S. Fish and Wildlife Service (Personal Communication).

Appendix H

LIST OF MISCELLANEOUS ANIMALS IN PITI CHANNEL AREA

Common Name	Scientific Name
Rat snake	*Bioga irregularis*
Monitor lizard	*Varanus indicus*
Green sea turtle*	*Chelonia mydas*
Hawksbill turtle*#	*Eretmochelys imbricata*

* Listed on Guam's proposed Endangered and Threatened Species list and are protected as threatened and endangered species, respectively, by Federal law.

\# Seldom reported anywhere in Guam waters; extremely unlikely in study area.

Source: U.S. Fish and Wildlife Service. *Proposed Commercial Port Expansion Project, Apra Harbor, Guam*, 28 February 1978.
Coret, Carl (U.S. Fish and Wildlife Service). Personal Communication, 9 February 1979.